15 MHz DUAL TRACE OSCILLOSCOPE

MODEL SO-4510

595-1523-04

OPERATION/SERVICE MANUAL

MP MASTER
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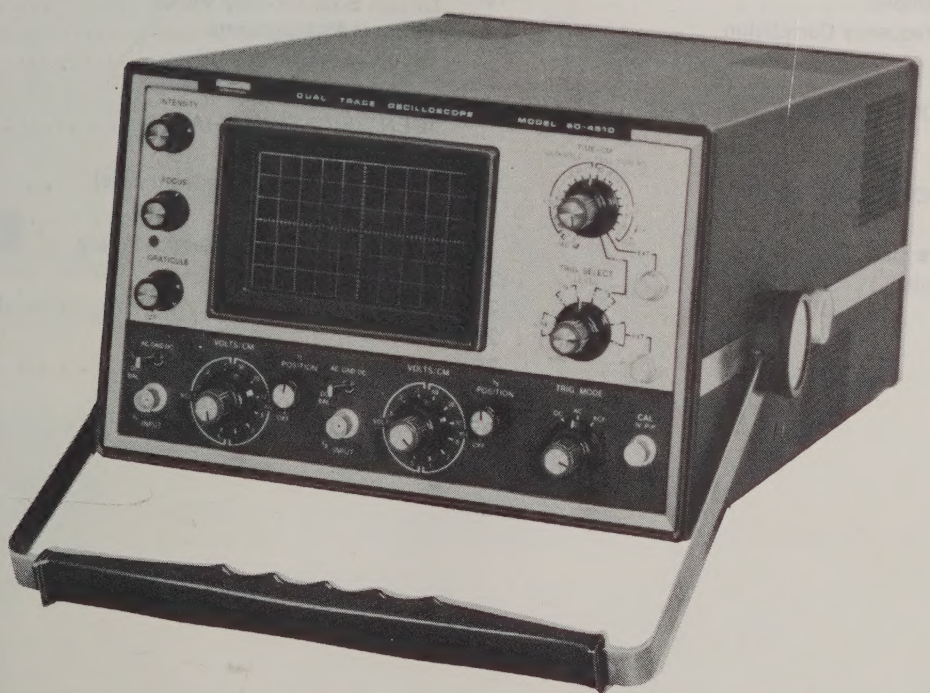

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INTRODUCTION

This Oscilloscope is a portable, triggered, dual trace, DC-to-15 MHz, laboratory-grade instrument. Outstanding features such as the fast vertical rise time, vertical delay lines, good trace brightness, and the high input sensitivity make the Oscilloscope ideal for the wide range of measurements typically encountered in electronics, development laboratories, and scientific research. In addition, the rugged construction and dependable operation make it a versatile tool for either the hobbyist or the service technician.

Each of the two identical input channels provides a maximum signal sensitivity of 1 millivolt/centimeter. Their attenuator networks can be switched through 12 calibrated ranges to set the deflection factor from 1 millivolt/centimeter to 5 volts/centimeter. An internal vertical delay line insures that the horizontal sweep starts before the beginning of the vertical signal. Thus, the complete vertical waveform will be displayed. Since amplifier rise time is 24 nanoseconds, very fast rise-time signals are faithfully reproduced.

Several modes of signal display are selected by each channel's position control and the Time Base switch. Either or both channels can be displayed as a function of time or as a function of each other. At slower sweep speeds, the vertical channel signals are alternately displayed at a 200 kHz (approximately) rate (chopped mode) so both signals appear as a function of the same time base. For faster sweep speeds, both signals are displayed alternately (alternate mode) on successive sweeps. During X-Y operation, the Channel Y1 (X) circuits provide horizontal (X axis) deflection and the Channel Y2 (Y) circuits provide vertical (Y axis) deflection.

Calibrated time-base-ranges from .2 seconds/centimeter to .1 microsecond/centimeter are readily switched in a 1-, 2-, 5-step sequence. A control on the Time Base switch provides variable sweep speeds between switch positions. Any sweep speed can be expanded 5 times when the X5 speed control is pulled out, giving a maximum sweep speed of 20 nS/centimeter.

The Trigger Select switch and Level control allow the time base to be precisely triggered at any point along the positive or negative slope of the trigger signal. Various trigger signals can be selected. These include a sample of Channel Y1 or Channel Y2 input signals, an externally applied trigger signal, or a sample of the line voltage. The Trigger Mode switch controls the trigger input bandpass, cutting off unwanted low frequency trigger signals.

A calibrated 1-volt peak-to-peak square wave signal is provided through a front panel connector, allowing easy probe compensation, vertical amplifier calibration, and comparison.

Front panel display controls include Intensity, Focus, Graticule illumination, and Vertical and Horizontal position. Two additional controls, accessible through the rear panel, adjust the Astigmatism and Geometry. An internal switch is used to match the regulated power supply to the line voltage from 100 volts to 280 volts AC.

Thus, this Oscilloscope combines the most desirable features required for precise measurement and display, while its solid-state circuitry provides the ultimate in sensitivity, stability, and versatility.

INTENSITY (R605) – Clockwise rotation increases the brightness of the display. Adjust for nominal brightness in your room-lighting condition. Refocusing may be necessary when the intensity is changed. CAUTION: Do not allow a bright spot to remain on the screen as it could damage the CRT.

FOCUS (R602) – Varies the size of the beam striking the face of the CRT. Adjust for the sharpest display.

POWER INDICATOR (PL601) – Glows when AC power is turned on.

GRATICULE (R608/S601) – In the full counterclockwise position AC power is turned off. As the control is turned clockwise, the Oscilloscope is turned on and the brightness of the graticule can be adjusted.

Channel Y1 (X)

AC-GND-DC (Input switch) S101-1 – In the AC position, this switch blocks the DC level of the input signal so that only the AC component is displayed. In the GND position, the input is disconnected and the vertical amplifier input is grounded. Use this position when you wish to set the baseline (trace) at a desired position without disconnecting the input signal. In the DC position, both the DC and AC components of the input signal are displayed.

Channel Y1 (X)

DC BAL (R119-1) – This is not an operating control. It should be used as directed in the "Operation" section of this Manual.

Channel Y1 (X)

INPUT – This is the Y1 input connector. It is also the X input connector during X-Y operation.

Channel Y1 (X)

VOLTS/CM (S102-1) – Each position of this attenuator switch is marked for the number of volts (peak-to-peak) required to produce a pattern one centimeter high on the graticule.

Channel Y1 (X)

VARIABLE (R128-1/S105-1) – This control is normally operated in its fully clockwise (CAL) position where the VOLTS/CM switch positions are calibrated. Vertical gain decreases as the control is turned counterclockwise, permitting the vertical trace size to be adjusted.

Channel Y1 (X)

POSITION (R148-1/S103-1) – In the fully counterclockwise (OFF) position, channel Y1 is turned off. This position (OFF) is used when only channel Y2 is being used. When this control is turned clockwise, the channel Y1 circuits are turned on and it positions the trace vertically on the screen (if channel Y2 is on, the circuits automatically switch to dual-trace operation). In the X-Y operation this control positions the spot horizontally on the screen.

TIME/CM (S401) – The time required for the beam to sweep one centimeter is determined by the TIME/CM switch when the VARIABLE control is fully clockwise (CAL). This switch also selects external horizontal (EXT) or X-Y operation.

VARIABLE-PULL FOR X5 (R428/S403) – Provides a continous adjustment of the sweep time between time base ranges. When pulled out, the sweep speed is effectively multiplied by 5.

EXT – This connector is used for external horizontal operation. A negative-going voltage moves the trace to the right.

TRIG SELECT (S402) – This control selects the source and polarity of the triggering signal:

Line (+/–) – Trigger signal is a portion of the 60 Hz line frequency.

Y1 (+/–) – Triggers on a signal from channel Y1 only.

Y2 (+/–) – Triggers on a signal from channel Y2 only.

EXT (+/–) – Triggers on a signal applied from an external source.

LEVEL (R411/S404) – Adjusts the trigger circuits so the sweep can be started at any position on the input signal waveform. The sweep can be started on either a positive or negative slope, depending on the position of the TRIG SELECT switch. When the TRIG MODE switch is in the DC position, this control selects the position on the graticule where triggering will occur. In its fully counterclockwise position (AUTO) the trigger circuits are in the automatic mode and will trigger at the zero crossing point of the input waveform. A base line will always be present in the AUTO position, even in the absence of a trigger signal.

EXT Input – An external signal can be applied through this connector to trigger the sweep circuits when the TRIG SELECT switch is in the EXT position.

CAL – This 1 volt (peak-to-peak) square wave signal (approximately 1000 Hz) can be used to periodically check vertical calibration. The fast rise time of this signal allows it to also be used for oscilloscope probe compensation.

TRIG MODE (S104) – The DC position couples the trigger signals directly to the trigger circuits. This allows the sweep to be triggered from DC level changes or very low frequency AC signals. In the AC position, the DC component of the trigger signal is blocked so that only the AC component of the signal reaches the trigger circuits. The ACF (AC Fast) position couples only the faster AC components of the trigger signal to the trigger circuits.

HORIZ POS (R213A/B) – Positions the trace or traces horizontally on the screen. This is a two-speed control. Turn it just past the desired point, and then turn it back slightly to use the two-speed feature.

Channel Y2 (Y)

POSITION (R148-2/S103-2) – In the fully counterclockwise (OFF) position, channel Y2 is turned off. This position (OFF) is used when only channel Y is being used. When this control is turned clockwise, the channel Y2 circuits are turned on and it positions the trace vertically on the screen (if channel Y1 is on, the circuits automatically switch to dual trace operation). In X-Y operation this control positions the spot vertically on the screen.

Channel Y2 (Y)

AC-GND-DC (Input switch) S101-2 – In the AC position, this switch blocks the DC level of the input signal so that only the AC component is displayed. In the GND position, the input is disconnected and the vertical amplifier input is grounded. Use this position when you wish to set the baseline (trace) at a desired position without disconnecting the input signal. In the DC position, both the DC and AC components of the input signal are displayed.

Channel Y2 (Y)

VARIABLE (R128-2/S105-2) – This control is normally operated in its fully clockwise (CAL) position where the VOLTS/CM switch positions are calibrated. Vertical gain decreases as the control is turned counterclockwise, permitting the vertical trace size to be adjusted.

Channel Y2 (Y)

DC BAL (R119-2) – This is not an operating control. It should be used as directed in the "Operation" section of this Manual.

Channel Y2 (Y)

INPUT – This is the Y2 input connector. It is also the Y input connector during X-Y operation.

Channel Y2 (Y)

VOLTS/CM (S102-2) – Each position of this attenuator switch is marked for the number of volts (peak-to-peak) required to produce a pattern one centimeter high on the graticule.

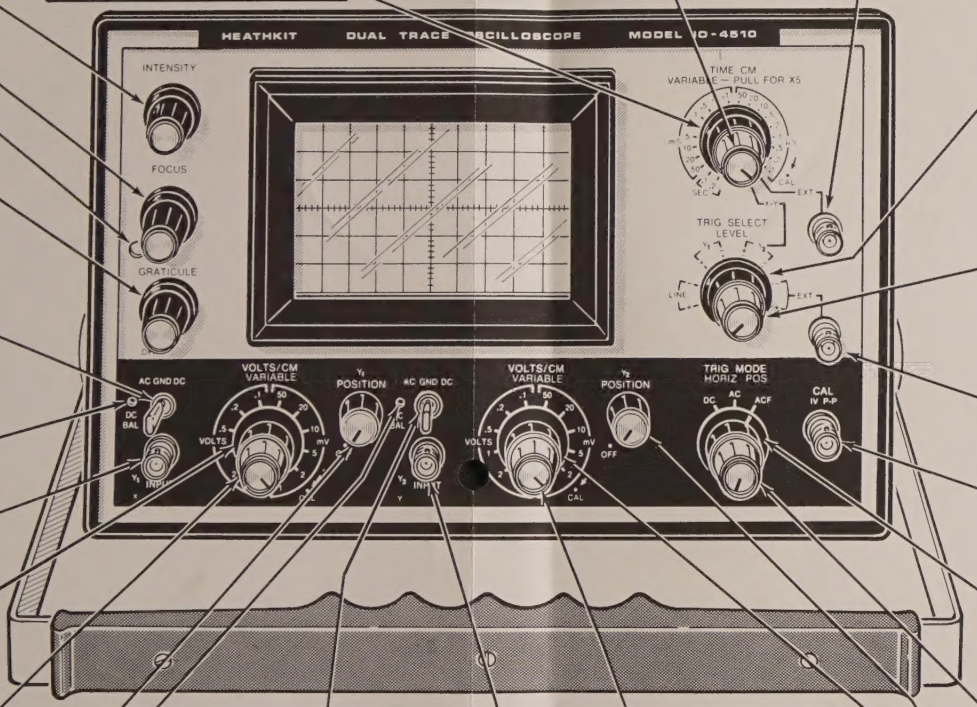


Figure 1

SPECIFICATIONS

VERTICAL

Input Impedance	1 MΩ shunted by 38 pF.
Maximum Input Voltage	400 volts peak combined AC and DC.
Sensitivity	1mV to 5V/cm in a 1-2-5 sequence, accurate to within 3%. Uncalibrated, continuously variable between steps, minimum sensitivity of approximately 15 V/cm.
Frequency Response	DC to 15 MHz (-3 dB).
Rise Time	24 ns.
Overshoot	Less than 3%.
Vertical Windows	2 minimum.
Vertical Modes	Channel Y1, channel Y2, Y1 and Y2 chopped, channels Y1 and Y2 alternately. Modes are selected by the channel Y1 position, channel Y2 position, and time base switch.
Vertical Position Stability Warm-up	30 minutes.

HORIZONTAL

Modes	Sweep, X-Y and external.
Time Base	.2S to .1 μS/cm in 22 calibrated steps, 1-2-5 sequence; accurate to within 3%. Uncalibrated, continuously variable between ranges, maximum of approximately 500 mS/cm.
X5 Sweep Magnifier	Accurate to within 5%
Input Impedance	Approxiamtely 200 kΩ.
Input Sensitivity	0.4V/cm (approximately). No attenuator; negative signal causes trace to move to right.
X-Y Sensitivity	1 mV to 5 V/cm in a 1-2-5 sequence.
X-Y Phase Shift	Less than 3° at 100 kHz.

TRIGGER

Delay Line	Allows display of at least 20 nS of the pretriggered waveform.
Bandwidth (normal mode at 1 cm deflection):	
AC	20 Hz – 30 MHz, typically 20 Hz – 45 MHz.
ACF	15 kHz – 30 MHz, typically 15 kHz – 45 MHz.
DC	DC – 30 MHz, typically DC – 45 MHz.
Bandwidth (automatic mode at 1 cm deflection)	DC – 10 MHz, typically DC – 25 MHz.
Sensitivity	Less than .5 cm.
External Input Sensitivity	Less than .5V, typically .1V.
External Input Impedance	1M shunted by approximately 30 pF.

GENERAL

CRT Acceleration Potential	4000V regulated.
CRT Type	6 X 10 cm Spiral PDA (Post Deflection Acceleration).
CRT Phosphor	P31.
Power Supplies	Fully regulated.
AC Line Switch	Allows operation from a 100-140 VAC or 200-280 VAC power source.
Power Requirements	100-140 VAC or 200-280 VAC, 50/60 Hz, 75 watts.
Input Connectors	Coaxial BNC.
Graticule Illumination	Adjustable from front panel.
Dimensions:	
Height	17.7 cm (6.937 in.).
Length (handle extended)	54.5 cm (21.5 in.).
Length (handle folded)	49 cm (19.25 in.).
Width	32.5 cm (12.875 in.).
Weight	11 kg (24 lbs.).
Operating Temperature	10°C to 40°C.

The Heath Company reserves the right to discontinue products and to change specifications at any time without incurring any obligation to incorporate new features in products previously sold.

OPERATION

This section of the Manual explains the function of each control, switch, and connector; gives a preset for each control and switch; describes how to correlate between time/cm and frequency; and provides information on operational examples.

CONTROL FUNCTIONS

Refer to Figure 1 (fold-out from Page 4) for the location and explanation of the front panel controls and switches.

PRESETTING CONTROLS

1. Set the front panel controls and switches as follows:

INTENSITY	Center of rotation
FOCUS	Center of rotation
GRATICULE	Fully counterclockwise (OFF)
HORIZ POS	Center of rotation
TRIG MODE	AC
TIME/CM	.1mS
VARIABLE – Pull for X5	Fully clockwise (CAL) and pushed in (X1)
TRIG SELECT	Y1, + (plus)
LEVEL	Fully counterclockwise (AUTO)
Y1:	
POSITION	Center of rotation
VOLTS/CM	50 mV
VARIABLE	Fully clockwise (CAL)
INPUT switch	GND
Y2:	
POSITION	Fully counterclockwise (OFF)
VOLTS/CM	50 mV
VARIABLE	Fully clockwise (CAL)
INPUT switch	GND

Before the Oscilloscope can be used, it must be warmed up and have the beam in the cathode ray tube properly adjusted on the screen. The following procedure will prepare the Oscilloscope for operation in any mode, and may be used at any time to check the basic instrument operation.

CAUTION: Always unplug the line cord before turning the line voltage switch.

NOTE: In the U.S.A., 120 VAC line voltage is most often used, while in other countries 220 VAC line voltage is more common. If the line voltage in your area is in the 120 VAC range, make sure the line voltage switch is set to the appropriate (110, 117, or 125) position. If the line voltage in your area is in the 220 VAC range, make sure the line voltage switch is set to the appropriate (220, 234 or 250) position.

2. Connect the line cord to an AC power source.

CAUTION: Do not permit a bright dot to remain on the face of the cathode ray tube for a prolonged period of time; a dot will burn the phosphors and leave a permanent image in the face of the CRT.

CAUTION: Do not operate the oscilloscope for any length of time with both vertical traces completely off the scope. This could cause damage to the Vertical Output circuitry.

3. Turn the GRATICULE control clockwise until the power indicator lights. Then turn the control further until the lines on the graticule over the screen of the CRT are illuminated. You may wish to readjust the scale illumination later.
4. Allow a minute or two for the instrument to warm up.
5. Slowly adjust the Y1 POSITION control and the HORIZ POS control to center the trace on the screen.
6. Adjust the INTENSITY control to obtain a trace just bright enough for your room lighting conditions.
7. Adjust the FOCUS control for the finest and sharpest trace.
8. Adjust the HORIZ POS control so the trace starts at the left edge of the graticule.

Your Oscilloscope is now prepared for operation in the modes described in the "Operational Examples" section.

DC BALANCE (DC BAL)

The highly sensitive vertical amplifier input circuits in this Oscilloscope, as in other sensitive equipment, may exhibit an occasional unbalance caused by aging components and temperature effects. Even though the DC BAL (balance) control is not considered to be an operating control, you should make it a habit to check the DC balance periodically and readjust it when necessary. This is especially true when you use the more sensitive input ranges (20 mV to 1 mV). A small screwdriver is needed to make this adjustment through the small hole in the front panel.

To check the DC balance of either channel, set the input switch (AC-GND-DC) to ground (GND) and obtain a trace on the CRT. Turn the VOLTS/CM VARIABLE gain control from fully clockwise to fully counterclockwise. If the trace moves vertically, the DC balance must be readjusted as follows:

1. Turn the VOLTS/CM switch to the 20 mV position.
2. Turn the VARIABLE gain control fully clockwise to the CAL position.
3. Center the trace on the screen.
4. Turn the VARIABLE gain control fully counterclockwise.
5. Adjust the DC BAL control to return the trace to the centerline.
6. Repeat steps 2 through 5 until the trace does not move when the VARIABLE gain control is turned.
7. Turn the VOLTS/CM switch to the 1 mV position and repeat steps 2 through 6.

NOTE: If the trace does not move as the VARIABLE gain control is turned, but moves when the VOLTS/CM switch is changed, perform the "Vertical Amplifier Balance" on Page 27.

NORMAL OPERATING CHARACTERISTICS

The following information is provided to help answer possible questions you may have about the operation of your Oscilloscope.

- It may require several minutes for the trace to stabilize when the Oscilloscope is first turned on, especially on the more sensitive voltage ranges. A short warm-up period (about 15 minutes) will help prevent this condition.

- The trace may move slightly on the more sensitive voltage ranges when the input switch is switched to ground and when measurements are made at different source impedances.

- The Trace may become slightly wider on the 1 millivolt/centimeter range. This is wideband noise generated by various components in the input circuits.

- Random noise on the input signal may cause false triggering especially on the most sensitive voltage ranges.

- The EXT (external) horizontal position of the TIME/CM switch is for single channel operation only. Select either Channel Y1 or Channel Y2 by turning the unwanted channel off before switching from a sweep position to the EXT horizontal position. If both Channel Y1 and Channel Y2 are turned on when the TIME/CM switch is switched to EXT, either channel may be displayed.

- When the TIME/CM switch is switched from the X-Y position to the EXT horizontal position, the Channel Y2 display circuits are turned on, even if the Channel Y2 POSITION control is turned off. This can be corrected if you: (A) turn the TIME/CM switch to a sweep position and then back to the EXT horizontal position (if Channel Y1 is to be used); or, (B) turn the Channel Y1 POSITION control off, and then turn the Channel Y2 POSITION control on and use the Channel Y2 amplifier.

- A baseline will automatically appear after a short pause when the trigger LEVEL control is turned to the AUTO position or when the input signal is disconnected when automatic triggering is used.

USING A 1 MILLIVOLT OSCILLOSCOPE

When you use an Oscilloscope as sensitive as this, you must use special care to make reliable measurements. Keep the following points in mind when you measure very low level signals.

- Placement of the ground clip may be critical if the signal source ground carries an appreciable current. Voltage differences of several millivolts from one side of a chassis or ground foil to the other are common. Place the ground clip at the point that gives the least error. This is usually nearest the signal source. The ground clip may have to be moved when you measure different points.

- Stray 60 Hz pickup may be hard to eliminate, especially in high impedance circuits. Be sure to use shielded test cables. Shield the signal source if necessary.

- Wideband measurements in the millivolt and submillivolt regions are more difficult because of the inherent noise (shot noise and thermal noise) generated by electronic components. This may appear as a widening of the baseline or the baseline appearing out of focus. Noise on the baseline that appears as "hash" or "spikes" may be caused by the electromagnetic pickup of man-made noise such as ignition noise, appliance noise, etc. Noise of any kind may cause erratic triggering.

- Radio frequency interference may be picked up in strong RF signal areas. This type of interference may come from a commercial broadcasting station or from nearby equipment.
- Thermal drift may also appear if the test clip is connected across a junction of two dissimilar metals or across a semiconductor. This will appear as a baseline drift when the junction changes temperature.

OPERATIONAL EXAMPLES

This section of the Manual gives several examples of how to use the Oscilloscope in its different modes of operation. These examples will help you become familiar with the controls, especially the sweep and triggering controls, and with dual-trace operation.

EXAMPLE 1

Triggering the Sweep on the + or — Slope of a Waveform

Signal source: Sine wave generator capable of a 1 kHz, 1 volt rms signal.

Be sure all controls and switches are in the positions described in "Presetting Controls." Do not change any of these settings unless you are directed to do so in a step. Connect the Y1 vertical input cable to the sine wave generator output. Place the Y1 INPUT switch (AC-GND-DC) in the AC position and set the VOLTS/CM switch to .5V. Be sure the VARIABLE control is fully clockwise.

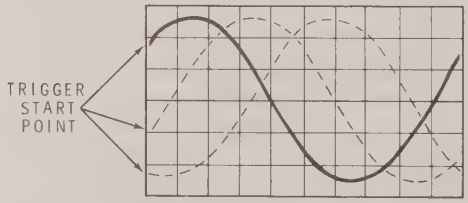


Figure 2

Turn the TIME/CM switch to the .1 mS position. (The VARIABLE—X5 control should be fully clockwise and pushed in.)

Turn the LEVEL control to the 12 o'clock position. Then turn it slightly each way from the center and observe the leading (left-hand) edge of the waveform. Note that the LEVEL control sets the point on the waveform when the sweep starts. See Figure 2.

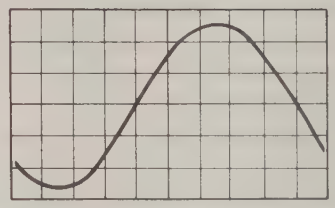


Figure 3

Change the TRIG SELECT switch to Y1 minus (—) and note that triggering now starts on the downward or negative slope of the waveform as in Figure 3. Vary the LEVEL control to move the starting point up or down on the slope.

Return the TRIG SELECT switch to the Y1 plus (+) position and the LEVEL control to center. Then set the INPUT switch to its center (GND) position and the trace will disappear.

The waveform will appear only when the INPUT switch is in either the AC or DC positions. Leave the Y1 INPUT switch in the AC position.

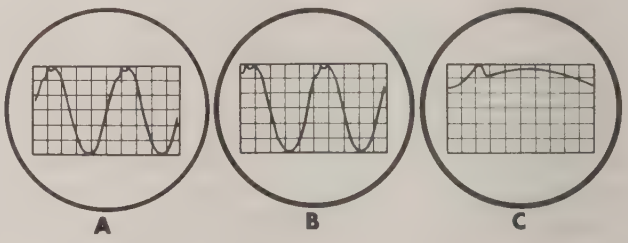


Figure 4

Now, assume that you want to examine the "spike" on waveform A of Figure 4. First, adjust the LEVEL control so the sweep starts just before the spike, as in B of Figure 4. Then decrease the time required for one complete sweep by changing the position of the TIME/CM and/or the X5 switch. The X5 expands the sweep around the center two centimeters. The spike is now spread across a large area of the screen for closer observation, as in C of Figure 4.

Read the TIME/CM and X5 switch settings to determine the duration of the spike. This feature is also useful to observe distortion in circuits using square wave signals.

The X5 function causes the beam to theoretically travel five times further. Thus, to sweep across one centimeter, the trace must now travel this distance in 1/5 the time specified by the TIME/cm switch. When the X5 magnifier is used (pulled out), the true sweep speed is found as follows:

$$\text{True time/cm} = \frac{\text{Time/cm}}{5} \text{ OR Time/cm (x) .2}$$

Example: Time/cm switch setting = 2 mS.
X5 switch pulled out.

$$\text{True time/cm} = \frac{2 \text{ mS}}{5} = 0.4 \text{ mS}$$

EXAMPLE 2

Normal or Automatic Triggering

The AUTO mode (automatic triggering) provides a base or reference line without the presence of a vertical input signal. This line is used as a reference point, especially for DC measurements.

With the controls and switches set as they were at the conclusion of Example 1, and with a waveform of the 1 kHz sine wave signal on the CRT, turn the LEVEL control fully counterclockwise to the AUTO position. The trace will appear as one complete cycle.

Make sure the TIME/CM switch is in the .1 mS position and the VARIABLE control is fully clockwise and pushed in.

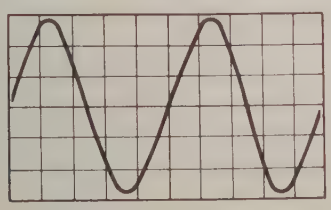


Figure 5

Slowly increase your signal generator frequency to 2 kHz and note that the display on the CRT remains locked in. At 2 kHz, two complete cycles of the input signal will be displayed as in Figure 5.

Automatic triggering, which occurs around the zero crossing point, is useful for simple waveforms.

EXAMPLE 3

Dual-Trace Operation

Signal source: Sine wave - square wave generator capable of in-phase, simultaneous, sine wave and square wave output, 1 kHz, 1 volt.

Connect the sine wave signal to the Y1 INPUT and the square wave signal to the Y2 INPUT.

Set both the Y1 and Y2 VOLTS/CM switches at 1V and both INPUT switches at AC; then set the following switches as indicated:

TRIG SELECT	Y1, plus (+)
TRIG MODE	AC
LEVEL	Fully counterclockwise (AUTO)
TIME/CM	.2 mS

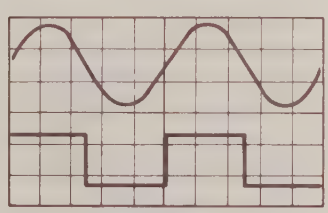


Figure 6

Adjust the Y1 and Y2 POSITION controls so the two waveforms are separated on the CRT. The display will be similar to that shown in Figure 6. Triggering occurs at the zero crossing of the sine wave signal.

NOTE: Either channel can be turned off by turning the respective POSITION control fully counterclockwise to the detent (OFF) position.

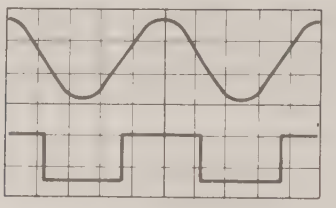


Figure 7

Turn the LEVEL control clockwise (to the normal mode) so triggering occurs at the peak of the sine wave as in Figure 7. Note that this is at the midpoint of the positive portion of the square wave.

Return the LEVEL control to the AUTO position (fully counterclockwise) and the waveforms will again appear in their generated phase relationship.

EXAMPLE 4

X-Y Mode Operation

With the TIME/CM switch in the X-Y position, and the TRIG SELECT in Y2, Y2 (Y) signals produce vertical deflection while Y1 (X) signals produce horizontal deflection. In the X-Y mode, the Y1 (X) controls and switches affect the horizontal display. Adjust the HORIZ POS control so the Y1 (X) POSITION control will move the spot off the screen in both directions.

Trapezoidal and Lissajous patterns that are useful in studying modulation characteristics, and frequency and phase comparisons, result from applying separate signals to the Y1 (X) and Y2 (Y) inputs in the X-Y mode.

TIME/CM-TO-FREQUENCY CORRELATION

Eleven vertical and seven horizontal lines on the graticule, spaced 1 centimeter apart, permit the measurement of displayed waveforms. The short markers on the centerlines are spaced 2 millimeters apart. Use the following formula or the Chart (fold-out from this page) to determine the frequency of a waveform displayed on the CRT.

TIME/CM switch* setting in seconds per cm. $\times \frac{1}{\text{MAGNIFIER}} \times$ Centimeters for 1 cycle of unknown frequency = Period of unknown frequency.

and, $\frac{1}{\text{Period}}$ = Frequency

EXAMPLE: If one cycle of a waveform measures 2 cm on the graticule, with the TIME/CM switch at 1 ms and the X5 switch pulled out, then —

$.001^{**} \times \frac{1}{5} \times 2 = .0004$, and $\frac{1}{.0004} = 2500$ Hz.

NOTES:

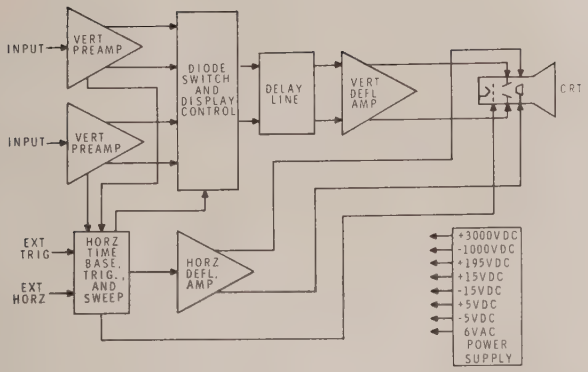
*The VARIABLE —X5 control must be fully clockwise to use the calibrated TIME/CM switch settings in this formula.

**1 millisecond = .001 second; 1 microsecond = .000001 second.

When the X5 switch is pulled out, the sweep travels 5 times further (theoretically), which makes the sweep time shorten by a factor of 5.

TIME/CM-TO-FREQUENCY CORRELATION CHART

	TIME/CM SWITCH	TIME FOR 1 CM SWEEP		FREQUENCY FOR 1 Cycle/1 CM	
		X5 IN	X5 OUT	X5 IN	X5 OUT
MICROSECONDS	0.1 μsec	0.1 μsec	0.02 μsec	10 MHz	50 MHz
	0.2 μsec	0.2 μsec	0.04 μsec	5 MHz	25 MHz
	0.5 μsec	0.5 μsec	0.1 μsec	2 MHz	10 MHz
	1 μsec	1 μsec	0.2 μsec	1 MHz	5 MHz
	2 μsec	2 μsec	0.4 μsec	500,000 Hz	2.5 MHz
	5 μsec	5 μsec	1 μsec	200,000 Hz	1 MHz
	10 μsec	10 μsec	2 μsec	100,000 Hz	500,000 Hz
	20 μsec	20 μsec	4 μsec	50,000 Hz	250,000 Hz
	50 μsec	50 μsec	10 μsec	20,000 Hz	100,000 Hz
	100 μsec	100 μsec	20 μsec	10,000 Hz	50,000 Hz
MILLISECONDS	0.2 msec	0.2 msec	40 μsec	5,000 Hz	25,000 Hz
	0.5 msec	0.5 msec	0.1 msec	2,000 Hz	10,000 Hz
	1 msec	1 msec	0.2 msec	1,000 Hz	5,000 Hz
	2 msec	2 msec	0.4 msec	500 Hz	2,500 Hz
	5 msec	5 msec	1 msec	200 Hz	1,000 Hz
	10 msec	10 msec	2 msec	100 Hz	500 Hz
	20 msec	20 msec	4 msec	50 Hz	250 Hz
	50 msec	50 msec	10 msec	20 Hz	100 Hz
SEC	.1 sec	0.1 sec	20 msec	10 Hz	50 Hz
	.2 sec	0.2 sec	0.04 sec	5 Hz	25 Hz



SYSTEM BLOCK DIAGRAM

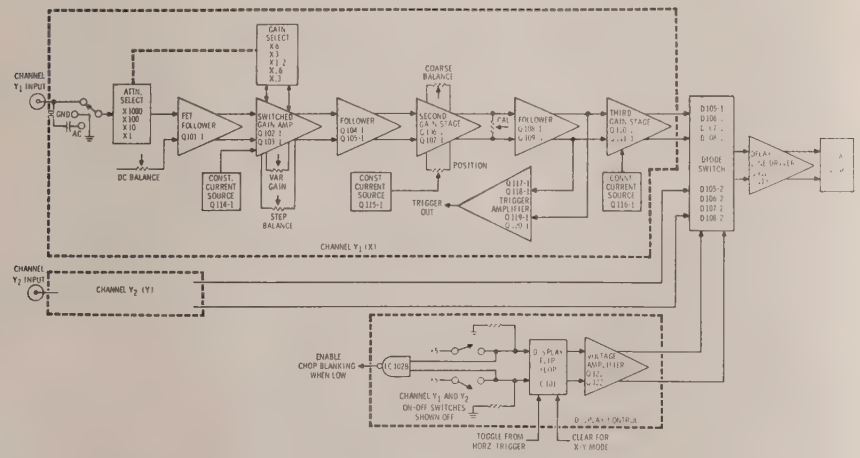


Figure 8

THEORY OF OPERATION

The dual-trace capability of this Oscilloscope allows two different signals to be displayed on a conventional CRT (cathode ray tube) that has only one set of vertical deflection plates. Two identical vertical preamplifier circuits, a switching circuit, and a vertical deflection amplifier make this possible. Each vertical preamplifier circuit attenuates its input signal by a known factor, amplifies it to a usable level, and provides the necessary positioning bias. The switching circuit (a diode-type switch), which is automatically controlled by the display control circuit, alternately allows the output signals from the two preamplifier circuits to pass through the delay lines to the vertical deflection amplfier. The delay lines delay the vertical signals slightly so the sweep starts before the vertical signal is displayed. The vertical signal, a composite of both input signals, is amplified further by the vertical deflection amplifier before it is applied to the vertical deflection plates of the CRT. The signal at the vertical deflection plates, which produces the display on the screen, thus represents both input signals as one "time-share" signal.

The horizontal portion of the trace displayed on the CRT screen is produced by the sweep and trigger circuits in conjunction with the horizontal deflection amplifier. The sweep circuit produces the linear signal (ramp) used to sweep the electron beam across the CRT screen at a constant rate. This circuit is switch controlled (by the Time/Cm switch) to provide twenty accurate sweep rates needed to view and measure almost all input signals. This circuit must be triggered either by a portion of one of the vertical input signals, by an external signal, or by a portion of the line frequency signal. However, in the absence of a trigger signal, an automatic baseline circuit produces a simulated trigger signal which causes the sweep circuits to operate while in the automatic mode. This insures that, even though no signal is applied, a reference baseline (trace) will appear on the screen. The sweep signal is coupled to the horizontal deflection amplifier where it is amplified before being applied to the horizontal deflection plates of the CRT. Other circuits within the horizontal amplifier also provide the necessary positioning bias.

At the end of each horizontal sweep, the blanking circuits (which are triggered by the sweep circuits) turn the trace off (blank it). This prevents a line (retrace) from being displayed as the electron beam returns to the left side of the screen to start a new trace.

Regulated power supply circuits insure overall accuracy as well as excellent control of the electron beam size and intensity.

CIRCUIT DESCRIPTION

Refer to the System Block Diagram (fold-out from Page 12) and the Schematic Diagram (fold-out from Page 81) as you read this "Circuit Description."

Components are numbered in the following groups:

1 – 99	Parts on the chassis.
100 – 299	Parts on the vertical circuit board.
400 – 499	Parts on the time base circuit board.
500 – 599	Parts on the deflection circuit board.
600 – 699	Parts on the control circuit board.
700 – 799	Parts on the power supply circuit board.

VERTICAL

The vertical preamplifier consists of two identical circuits: one for Channel Y1 and the other for Channel Y2. Components in the Channel Y1 vertical preamplifier circuit are designated by a -1 suffix, while those in the Channel Y2 vertical preamplifier are designated by a -2 suffix. (For example: The Channel Y1 AC coupling capacitor is C101-1, while the Channel Y2 AC coupling capacitor is C101-2.) Components without a suffix do not relate to a specific channel. Since both channels are identical, only Channel Y1 is described in this "Circuit Description." See Figure 8 (fold-out from Page 14).

INPUT CIRCUIT

When the Y1 Input switch (AC-GND-DC) is in the DC position, a signal applied to the Y1 input connector is coupled through resistor R101-1 to the attenuator. Resistor R101-1 reduces the possibility of circuit oscillation. When the Y1 Input switch is in the AC position, the signal is coupled through capacitor C101-1, which passes only AC signals. This permits an AC signal superimposed on a DC potential to be seen without the DC component being displayed. The GND position of this switch disconnects the input signal and grounds the attenuator input. This allows the trace to be adjusted to a zero reference without disconnecting the test leads from the circuit under test.

Because the second (Q106-1/Q107-1) and third (Q110-1/Q111-1) differential amplifiers, which will be discussed later, operate at a fixed gain, any signal applied to them must be within a usable range (approximately 0-6 millivolts/centimeter). Therefore, the primary purpose of the vertical input circuits is to reduce the input signal by a known factor to this usable range.

The vertical input circuit basically consists of an attenuator and a switched-gain amplifier. These two circuits function together, through the VOLTS/CM switch, to provide the total desired signal attenuation. The attenuator obtains its four attenuation factors (1, 10, 100, and 1000) from four divider networks (resistors R102-1, R103-1, R104-1, R105-1, R106-1, and R107-1, and capacitors C104-1, C105-1, C108-1, C109-1, C113-1, and C114-1). At DC and low AC frequencies, the resistive dividers reduce the input signal level; while at higher frequencies, attenuation is determined by the resistor-capacitor (RC) networks. Capacitors C102-1, C106-1, C111-1, and C115-1 are adjusted during calibration to make the input capacitance of the Oscilloscope equal on all positions of the Volts/Cm switch when an attenuation probe (usually X10) is used.

The switched-gain amplifier portion of the vertical input circuit consists of an input source follower, a DC balance circuit, a constant current source, a switched-gain differential amplifier, and an output emitter follower circuit. The attenuated input signal is coupled through the resistors R115-1 and R114-1, and capacitor C121-1 to the gate of the input source follower, transistor Q101A-1. Capacitor C121-1 forms a high frequency signal path around R114-1 for improved frequency response. Reverse biased diodes D101-1 and D102-1 limit the voltage applied to the gate of Q101A-1 to a maximum of ±15 volts. This prevents damage to the transistor if the Volts/Cm switch is in a low range and a high potential is applied to the input. Transistor Q101A-1, one half of a dual field-effect transistor (FET), provides a high input impedance that is necessary to prevent loading of the attenuator circuit and a low output impedance to drive transistor Q102-1. To compensate for the DC voltage present at the source of Q101A-1 when no signal is applied, Q101B-1 (the other half of the dual FET) forms a DC balance circuit. Zener diodes ZD103-1 and ZD104-1 provide a stable reference voltage across DC BAL control R119-1. This control is adjusted so that the static DC source voltage of Q101B-1 is the same as the static DC source voltage of Q101A-1. This type of dual source follower input circuit provides excellent temperature and drift compensation.

Transistor Q114-1 forms a constant current source for the switched-gain differential amplifier (Q102-1/Q103-1). A voltage divider formed by resistors R136-1 and R137-1 holds the base of Q114-1 at a constant voltage. This, in turn, biases the transistor to hold the current through R135-1 and the switched-gain differential amplifier constant.

A switched-gain differential amplifier is formed by transistors Q102-1 and Q103-1. This direct-coupled differential amplifier provides a double-ended output from a single input signal. Since the current supplied to these transistors is constant, an increase in current through Q102-1 for example, causes a corresponding but opposite decrease in current through Q103-1. Thus, as Q102-1 amplifies the input signal, Q103-1 produces an equal but opposite signal. This creates a push-pull effect on the signal, which is amplified in the following stages to drive the vertical deflection plates of the CRT. Variable vertical gain is controlled by R128-1 when the Variable control is turned from its CAL (fully clockwise) position.

Five switch-selected resistor-capacitor networks set the gain of this switched-gain differential amplifier at 6, 3, 1.2, .6, and .3. The following chart shows how the Volts/Cm switch selects the various attenuation factors and gains of the switched-gain amplifier to provide the desired total gain.

To illustrate how the attenuator and switched-gain amplifier work together to provide the proper gain, assume the Volts/Cm switch is in the 1 mV position and a 1 mV signal is applied to the input. Since the total gain factor is 6, the input signal is amplified by a factor of six before it is applied

VOLTS/CM POSITION	ATTENUATION FACTOR	AMPLIFIER GAIN	TOTAL GAIN FACTOR
5 V	- 1000	X 1.2	X .0012
2 V	- 100	X 3	X .003
1 V	- 100	X 6	X .006
500 mV	- 100	X 1.2	X .012
200 mV	- 10	X 3	X .03
100 mV	- 10	X 6	X .06
50 mV	- 10	X 1.2	X .12
20 mV	- 1	X 3	X .3
10 mV	- 1	X 6	X .6
5 mV	- 1	X 1.2	X 1.2
2 mV	- 1	X 3	X 3
1 mV	- 1	X 6	X 6

through the emitter follower circuits of Q104-1/Q105-1 to the second differential amplifier (Q106-1/Q107-1). A 6-millivolt signal applied to the second differential amplifier will cause a 1 cm deflection on the CRT screen. Now assume the Volts/Cm switch is in the 500 mV position and a 500 mV signal is applied to the input. The total gain factor is now .012. Again multiplying the input signal by the total gain factor results in a 6 mV signal to the input of the second deflection amplifier (500 mV x .012 = 6 mV). Again causing a 1 cm deflection on the CRT screen.

Differential emitter followers (Q104-1/Q105-1) serve as a buffer between the amplifiers.

The second differential amplifier, Q106-1/Q107-1, has a gain of approximately 6. Vertical trace position is set with control R148-1 which offsets the constant current balance between Q106-1 and Q107-1, and causes one amplifier to conduct harder than the other. Coarse Balance control R150-1 balances the collector currents of Q106-1 and Q107-1. Calibrate control R157-1 sets the gain of the complete vertical channel from Input to CRT.

The signal from the second amplifier is coupled through the differential followers, Q108-1/Q109-1, to the third amplifier, Q110-1/Q111-1. This differential amplifier also has a gain of approximately 6. Its output is direct-coupled to the diode-type switch. The diode switch will be described later.

TRIGGER AMPLIFIER

A differential amplifier and follower comprise the trigger amplifier circuit. Its output is used to supply a trigger signal to the horizontal time base, trigger, and sweep circuit. In addition, the channel Y1 trigger signal can be switched to the horizontal deflection circuit for X-Y operation.

The vertical preamplifier signal, at the emitters of Q108-1 and Q109-1, is picked off and coupled to the input of the differential amplifier in the trigger amplifier circuit. Emitter follower Q120-1 couples the trigger signal from the inverting leg (Q118-1) of the differential amplifier (Q117-1/Q118-1) to the horizontal time base, trigger, and sweep circuit. To insure that the differential amplifier remains balanced, diode D105-1 is connected to the collector of Q118-1. This provides compensation for the base-emitter voltage drop of the follower. Transistor Q119-1 is the constant current source for this circuit. The DC Trigger control in the emitter leg adjusts the current so that the output of the follower will be zero with no signal to the trigger amplifier.

Gain of the Y1 trigger amplifier is adjustable between 5 and 7, to accommodate any gain differences between the vertical and horizontal deflection amplifiers in X-Y operation. Control R170-1 sets the overall gain of the X channel so that it is equal to the Y channel. The Y2 trigger amplifier operates with a fixed gain of approximately 6.

VERTICAL SWITCHING

Both vertical preamplifier circuits (channel Y1 and Y2) share the vertical deflection amplifier. This is accomplished with two high-speed diode switch networks (D107-1 thru D110-1 and D107-2 thru D110-2) that are actuated by the display control circuit. When one diode switch is turned on, the other is turned off so that only one signal can be coupled to the vertical deflection amplifier. Two-channel operation is accomplished by turning each diode switch network on and off at a rapid rate or, on alternate display sweeps.

NOTE: Transistor transistor logic (TTL) levels are as follows: A logic 0, or low, is < 0.8 volts. A logic 1, or high, is > 2.0 volts but < 5.5 volts.

The status (turned on or off) of both diode switch networks is determined by display flip-flop IC101, a J-K flip-flop. If, for example, channel Y1 is turned on with the Y1 Position control/switch, the $\overline{Q}$ output of IC101 will go low, and voltage amplifier Q121 will turn on and reverse bias diodes D107-1 and D108-1. Diodes D109-1 and D110-1 are then forward biased and the signal from Channel Y1 is coupled to the delay line driver. With $\overline{Q}$ low, Q is high, and Q122 is turned off. Diodes D107-2 and D108-2 are forward biased, and D109-2 and D110-2 are reverse biased, which blocks the channel Y2 signal. The reverse occurs when channel Y1 is turned off and channel Y2 is turned on. When both channels are turned on, the Q and $\overline{Q}$ outputs of IC101 alternately switch high and low at a rate determined by the horizontal trigger toggle. However, for X-Y operation, the Channel Y2 (Y) diode switch is forced on by the clear signal to IC101 and the channel Y1 (X) trigger output is coupled to the horizontal deflection amplifier through the Time/Cm switch.

The two front panel Position control/switches also control the chop blanking gate, IC102B. With both channels turned on, chop blanking is enabled. This is described further in the horizontal time base, trigger, and sweep circuit.

The output from the diode switch is coupled through the delay line driver (differential follower) to the delay line. The driver is used to isolate the delay line from the diode switch. The delay line delays the vertical signal for approximately 200 nS so that the horizontal circuits have time to function.

HORIZONTAL TIME BASE, TRIGGER, AND SWEEP CIRCUITS

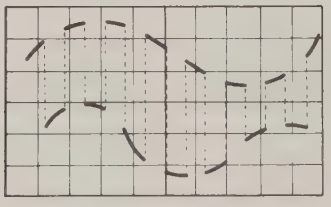


Figure 10

Refer to the detailed circuit diagram, Figure 9 (fold-out from Page 21) as you read the description that follows.

On command, from a trigger pulse, the horizontal time base circuits generate a linear ramp signal (sweep) to drive the CRT horizontal deflection plates. In the automatic triggering mode, if no trigger is present, the internal oscillator triggers the sweep, through the auto-baseline control. The oscillator also provides the vertical signal chop rate when two traces are displayed in the chop mode (Time/Cm sweep rate is 2 mS and slower.) Figure 10 shows a typical, two-trace, chopped display that has been exaggerated for clarity.

When a trigger pulse of sufficient amplitude is present, the trigger comparator outputs change logic state and activates the slope selector gate. A signal from the gate turns on the sweep control and allows the timing capacitor to be charged through the constant current source. The charging of the capacitor produces a linear ramp signal that is coupled through the voltage follower to the horizontal deflection circuits.

The ramp signal is also coupled to the sweep length comparator. When the ramp reaches a preset voltage level, the comparator triggers the blanking flip-flop, which activates the blanking control, The retrace hold-off monostable, which was also triggered, insures that retrace will not occur until after the CRT has blanked.

OSCILLATOR

A 200 kHz signal is generated by two NAND gates (IC401B and C) and their associated components wired as an oscillator. This is coupled to the mode selector as a chop signal. It is also coupled to IC407A for auto-baseline generation.

TRIGGER

In the automatic triggering mode, the trigger circuit examines the trigger signal for a proper trigger point. If the signal is large enough, the sweep circuit is activated. If the signal is insufficient or absent, the auto-baseline generator is activated.

Depending on the desired trigger mode, one of four sources can be selected by the Trig Select switch: Line Sync, Channel Y1 Trigger, Channel Y2 Trigger, or External Trigger. The Line Sync signal is tapped directly off of one side of the 6-volt transformer winding, the Channel Y1 and Y2 Trigger signals are provided by the vertical preamplifier trigger circuits, and the External Trigger signal is coupled through FET follower Q405 to the Trig Select switch. Reverse-biased zener diodes ZD401 and ZD402 limit the signal level to the gate of Q405. FET Q406 is a constant current source.

The trigger signal is coupled from Trig Select switch, through the Trig Mode switch, to the − input of trigger comparator IC405. The trigger comparator compares the trigger voltage at the − input (pin 5) to the reference voltage at the + input (pin 4). If the voltage at the − input, is greater than the reference voltage at the + input, the noninverting output (pin 11) is at a logic high and the inverting output (pin 10) is low. When the trigger voltage goes lower than the reference voltage, the comparator outputs will switch levels; the noninverting output will go low and the inverting output will go high. In like manner, when the trigger voltage goes higher than the reference, the comparator outputs will again change state. Thus each trigger pulse, of sufficient amplitude, is converted to a logic pulse. In "normal" operation, Level control R411 adjusts the reference voltage at the + input of the comparator. (Diodes D406 and D407 set the range of the control to approximately ±0.7 volts.) In "automatic" operation, the Level control is connected to ground for a zero volt reference level (zero-crossing trigger).

The complementary comparator output is coupled to ± slope selector gate IC406 and through differentiators to auto-baseline control IC410. (Feedback resistor R412 supplies circuit hysteresis so that the comparator will not switch on noise pulses.)

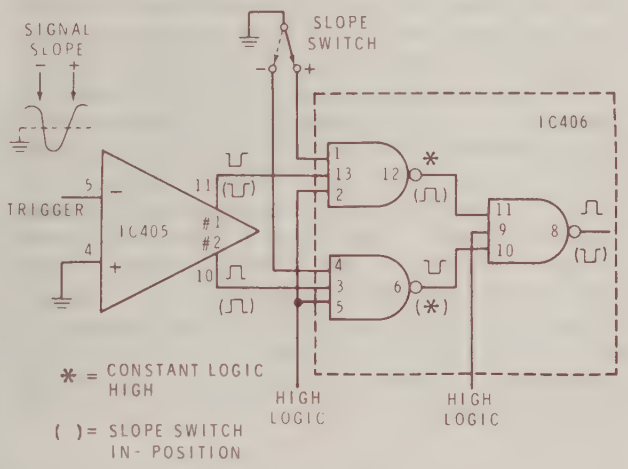


Figure 11

Trigger slope selection is determined by the Trig Select switch and the ± slope selector gate, IC406 as shown in Figure 11. The control lines to IC406 (pins 2 and 5) are normally held high by auto-baseline control IC410. If no trigger signal is present, the auto-baseline control (a retriggerable monostable) will "time-out" and clamp pins 2 and 5 of IC406 low. It will also turn on gate IC407A and allow the 200 kHz oscillator signal to be coupled to the sweep control. This will produce a reference baseline. When a trigger signal is present, the level transition at the output of the comparator gererates a negative pulse through one of the two differentiators. This triggers the monostable (IC410) on. The oscillator signal is switched off and the trigger signal is gated through IC406. Each additional trigger signal continues to hold the monostable on. If the trigger rate is less than 4/second, the monostable will time-out and generate a baseline between trigger pulses. During retrace, the Q output of IC404B (pin 9) holds pin 3 of IC410 low. This inhibits the trigger signal during retrace.

In the normal triggering mode, IC410 is preset and the auto-baseline circuit is inhibited. The exact trigger point is then adjusted by the Level control.

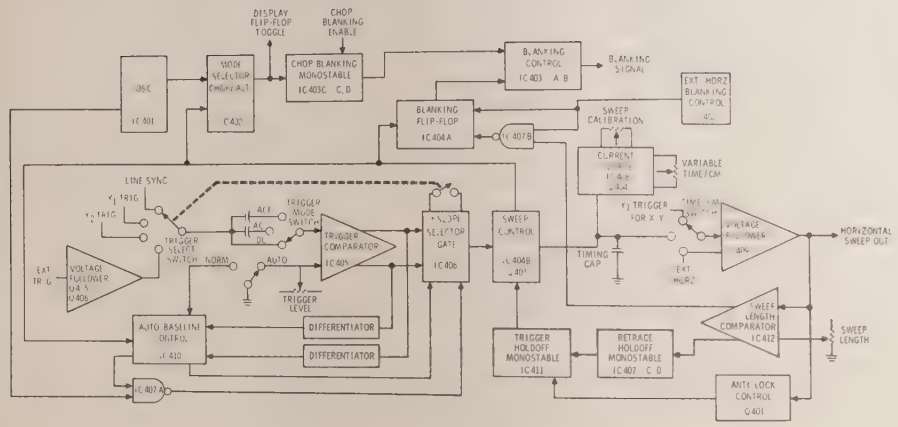


Figure 9

chop mode, the oscillator signal is coupled through de selector to toggle the display control circuit at a lz chop rate. The toggle is also used to trigger chop g monostable IC403C, D that has been enabled by splay control circuit (IC102B). The monostable es a short CRT blanking pulse that occurs at the time cal channel switch. This hides any possible noise that e displayed when the channels switch. In single operation, the Monostable is disabled to block the ggle. During retrace, diode D409 is forward-biased to and diode D408 is reverse-biased through D409. ocks the oscillator signal to prevent any possible false signals from coupling back through the vertical

ther sweep methods can be used to drive the ital deflection amplifier. The first is an externally applied signal. This is coupled through resistor R461, capacitor C432 (high frequency by-pass), and the Time/Cm switch to voltage follower IC409. Diodes ZD404 and ZD405 limit the external signal level for circuit protection. When an external horizontal signal is switched into the follower, external horizontal blanking control Q402 is switched into the blanking circuit and presets the blanking flip-flop to hold the CRT unblanked. The remaining trigger and sweep circuits are bypassed.

The other sweep method is when the Time/Cm switch is rotated to the X-Y position. The Channel Y1 trigger signal is coupled to voltage follower IC409. Display control IC101 is preset so that the Channel Y2 signal is switched to the vertical deflection amplifier and blanking control IC403A, B is set low so that the CRT remains unblanked.

CRT CONTROL

he vertical and horizontal deflection amplifiers use ital amplifier circuits similar to the vertical lifier. Their function is to increase the deflection mplitude to a level sufficient to deflect the CRT The blanking amplifier regulates the CRT electron by placing a high potential (inhibit the electron beam) round potential (pass the electron beam) on grid g G2 of the CRT. Refer to Figure 13 for a general of the circuits involved.

TICAL DEFLECTION AMPLIFIER

tput of the delay line is coupled across delay line tion resistors R501 and R502 to the first vertical ion amplifier. Control R502 is adjusted so the ssion line characteristics are matched and no signal ons occur. (Improper termination is characterized by p" in a square wave signal.) The first amplifier, Q502, supplies a signal gain of approximately 10 and t coupled to the second deflection amplifier. Controls and R505 adjust for low-frequency square wave nsation in the first amplifier.

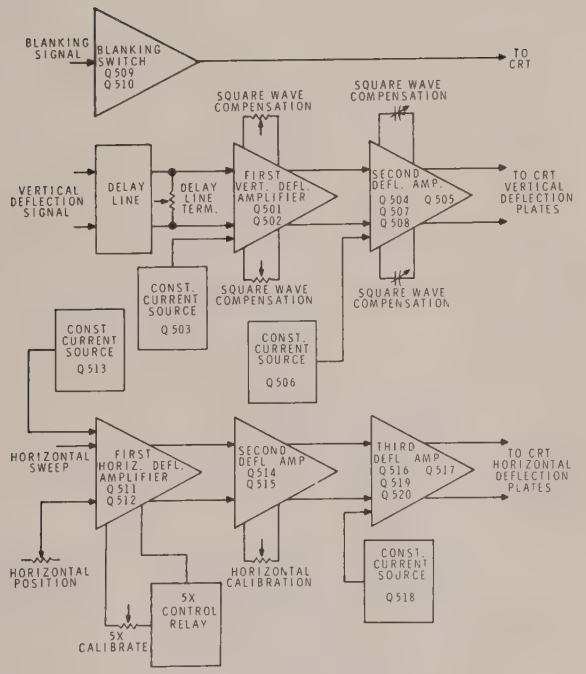
cond deflection amplifier; Q504, Q505, Q507, and is wired in a differential cascode configuration, with a approximately 10. Trimmers C503 and C504, across itters of Q504 and Q505, adjust for high-frequency wave compensation. Ferrite beads FB501 and FB502 e common-base amplifier, Q507/Q508, prevent ions in the amplifier. Circuit loading is provided by 's R525, R526, R527, and R528, while inductors nd L502 serve as peaking coils. The output of this ier is coupled to the vertical deflection plates of the CRT for beam control. Vertical beam deflection requires between 8 and 12 volts/cm, depending on individual CRT characteristics. The vertical channel calibrate control located in the vertical preamplifier adjusts overall vertical gain to match the CRT deflection characteristics.

HORIZONTAL DEFLECTION AMPLIFIER

The horizontal signal is coupled from the voltage follower, IC409, to the base of Q511 in the first horizontal deflection amplifier. A reference voltage from the horizontal position control provides a coarse (R213A) and fine (R213B) offset adjustment at the differential amplifier. Normal gain of the amplifier is 2, but for expanded sweep, the gain is switched to 10. A relay switches in 5X control R539, which sets the gain of the amplifier in the X5 mode.

The second deflection amplifier gain is adjustable between 2 and 4.5. This is set with horizontal calibration control R549 to produce a 1 cm beam deflection with a .2-volt (approximately) signal applied at the horizontal input (base of Q511). Resistor R555 serves as a long-tail constant current source.

Final amplification occurs in the third deflection amplifier. It is a cascode differential amplifier with a gain of approximately 18. The output is coupled to the horizontal deflection plates of the CRT for beam control. Horizontal beam deflection will require between 15 and 19 volts/cm depending on individual CRT characteristics.



CRT CONTROL AMPLIFIERS

Figure 13

SWEEP

A negative-to-positive transition from IC406 (pin 8) will toggle sweep control flip-flop IC404B and turn off switch Q403. Diode D411 reduces the voltage level to the base of Q403. When Q403 turns off, timing capacitor C426 or C427 is allowed to charge from constant current source IC408 and Q404. The capacitor used is determined by the Time/Cm switch.

In the constant current source, temperature-compensated zener diodes ZD412 and ZD413 maintain a regulated reference voltage, This regulated voltage is coupled through calibration control R431, R423, and Variable sweep control R428 to the noninverting (+) input of operational amplifier IC408. Dual calibration control R431/R423 adjusts the charging current of the timing capacitors. Variable control R428 is calibrated at full clockwise rotation. As it is rotated counterclockwise, the voltage at IC408 is decreased. This causes the constant current to decrease and thus decreases the sweep "speed." Since IC408 is wired as a voltage follower, the source of FET Q404 is connected to the inverting input of IC408. The amplifier insures that the voltage at the inverting input is held constant regardless of the load. Thus, each resistor selected by the Time/Cm switch will produce a constant current to charge either timing capacitor at a linear rate.

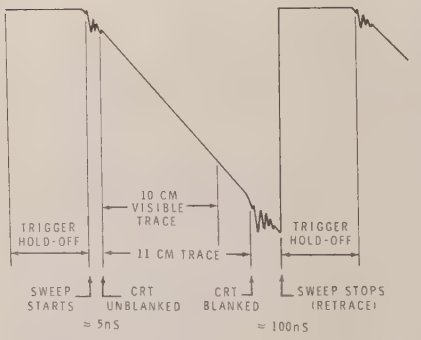


Figure 12

Refer to Figure 12 for a typical ramp waveform. When sweep control IC404B turns off switch Q403 and removes the short across the timing capacitor, the capacitor begins to charge and generate a linear, negative voltage ramp. At the same time, the start sweep signal toggles blanking flip-flop IC404A, which in turn unblanks the CRT through blanking control IC403A, B. The very short delay caused by the blanking circuits masks any possible switch noise on the ramp.

The negative voltage ramp is coupled through voltage follower IC409 to the horizontal deflection amplifier circuit and the sweep length comparator, IC412. The high impedance follower assures linearity and isolates the sweep circuit from the deflection amplifier circuit. Diode D415 provides a positive-voltage clamp to remove any positive noise pulses on retrace.

Sweep Length control R437 sets the reference voltage for sweep length comparator IC412 so that the ramp will travel approximately 11 cm across the CRT before the comparator switches. During the ramp-charge-time, output 1 (pin 11) is at logic 0 and output 2 (pin 10) is at logic 1. When the ramp voltage exceeds the reference voltage, the outputs will switch logic levels. Feedback resistors R432 and R433 provide circuit hysteresis to reduce the possibility of noise triggering the comparator.

Output 1 (pin 11 of IC412) is gated through IC407B to the clear (CL) input of blanking flip-flop IC404A and blanks the CRT. Output 2 (pin 10) is coupled to the retrace hold-off monostable (IC407C and IC407D) which provides about 100 nS of delay before the trigger hold-off monostable (IC411) is toggled. This allows any noise pulses produced by the switch circuit to occur after the CRT blanks. When trigger hold-off monostable IC411 is fired, IC404B of the sweep control clears and transistor Q403 turns on, discharging the timing capacitor to ground (retrace). A new sweep cannot start until IC411 "times-out." This is determined by the capacitor selected by the Time/Cm switch. At the end of hold-off, the next trigger pulse will start a new ramp.

When the Oscilloscope is first turned on, it is possible for the sweep circuit to hang-up and generate a ramp greater than 2 volts. Anti-lock control Q401 will turn on at approximately 4 volts and reset IC411 and IC404B.

For a two-channel display, the mode selector, IC402, controls the display control circuit. In alternate channel operation, the oscillator signal is blocked at the mode selector. The retrace, sweep-start signal transition from sweep control IC404B is coupled through the mode selector and toggles the display control circuit to change vertical input channels. The toggle, coupled to the chop blanking monostable, has no effect on the display since it occurs during the time the CRT is blanked.

In the chop mode, the oscillator signal is coupled through the mode selector to toggle the display control circuit at a 200 kHz chop rate. The toggle is also used to trigger chop blanking monostable IC403C, D that has been enabled by the display control circuit (IC102B). The monostable generates a short CRT blanking pulse that occurs at the time of vertical channel switch. This hides any possible noise that may be displayed when the channels switch. In single channel operation, the Monostable is disabled to block the chop toggle. During retrace, diode D409 is forward-biased to ground, and diode D408 is reverse-biased through D409. This blocks the oscillator signal to prevent any possible false trigger signals from coupling back through the vertical circuits.

Two other sweep methods can be used to drive the horizontal deflection amplifier. The first is an externally applied signal. This is coupled through resistor R461, capacitor C432 (high frequency by-pass), and the Time/Cm switch to voltage follower IC409. Diodes ZD404 and ZD405 limit the external signal level for circuit protection. When an external horizontal signal is switched into the follower, external horizontal blanking control Q402 is switched into the blanking circuit and presets the blanking flip-flop to hold the CRT unblanked. The remaining trigger and sweep circuits are bypassed.

The other sweep method is when the Time/Cm switch is rotated to the X-Y position. The Channel Y1 trigger signal is coupled to voltage follower IC409. Display control IC101 is preset so that the Channel Y2 signal is switched to the vertical deflection amplifier and blanking control IC403A, B is set low so that the CRT remains unblanked.

CRT CONTROL

Both the vertical and horizontal deflection amplifiers use differential amplifier circuits similar to the vertical preamplifier. Their function is to increase the deflection signal amplitude to a level sufficient to deflect the CRT beam. The blanking amplifier regulates the CRT electron beam by placing a high potential (inhibit the electron beam) or a ground potential (pass the electron beam) on grid blanking G2 of the CRT. Refer to Figure 13 for a general layout of the circuits involved.

VERTICAL DEFLECTION AMPLIFIER

The output of the delay line is coupled across delay line termination resistors R501 and R502 to the first vertical deflection amplifier. Control R502 is adjusted so the transmission line characteristics are matched and no signal reflections occur. (Improper termination is characterized by a "step" in a square wave signal.) The first amplifier, Q501/Q502, supplies a signal gain of approximately 10 and is direct coupled to the second deflection amplifier. Controls R504 and R505 adjust for low-frequency square wave compensation in the first amplifier.

The second deflection amplifier; Q504, Q505, Q507, and Q508; is wired in a differential cascode configuration, with a gain of approximately 10. Trimmers C503 and C504, across the emitters of Q504 and Q505, adjust for high-frequency square wave compensation. Ferrite beads FB501 and FB502 in the common-base amplifier, Q507/Q508, prevent oscillations in the amplifier. Circuit loading is provided by resistors R525, R526, R527, and R528, while inductors L501 and L502 serve as peaking coils. The output of this amplifier is coupled to the vertical deflection plates of the CRT for beam control. Vertical beam deflection requires between 8 and 12 volts/cm, depending on individual CRT characteristics. The vertical channel calibrate control located in the vertical preamplifier adjusts overall vertical gain to match the CRT deflection characteristics.

HORIZONTAL DEFLECTION AMPLIFIER

The horizontal signal is coupled from the voltage follower, IC409, to the base of Q511 in the first horizontal deflection amplifier. A reference voltage from the horizontal position control provides a coarse (R213A) and fine (R213B) offset adjustment at the differential amplifier. Normal gain of the amplifier is 2, but for expanded sweep, the gain is switched to 10. A relay switches in 5X control R539, which sets the gain of the amplifier in the X5 mode.

The second deflection amplifier gain is adjustable between 2 and 4.5. This is set with horizontal calibration control R549 to produce a 1 cm beam deflection with a .2-volt (approximately) signal applied at the horizontal input (base of Q511). Resistor R555 serves as a long-tail constant current source.

Final amplification occurs in the third deflection amplifier. It is a cascode differential amplifier with a gain of approximately 18. The output is coupled to the horizontal deflection plates of the CRT for beam control. Horizontal beam deflection will require between 15 and 19 volts/cm depending on individual CRT characteristics.

BLANKING AMPLIFIER

CRT blanking occurs when the voltage at the blanking grid (pin 5) is approximately 68 volts, while unblanking occurs when the blanking grid voltage is less than 4 volts. This grid voltage is determined by the voltage at the collector of blanking amplifier transistor Q510.

When the output of blanking control IC403B is high (logic 1), 5 volts is applied through resistors R529 and R531 to the base of blanking amplifier Q510, turning it on. Since the collector voltage is low (less than 4 volts) when Q510 is turned on, the CRT is unblanked.

When the output of blanking control IC403B goes low (logic 0), the base of Q510 also goes low, turning it off. As Q510 turns off, the collector voltage increases to the level (approximately 68V) set by diodes D501 and ZD502, blanking the CRT. However, because of its high impedance load (R535), the turnoff time of Q510 does not happen immediately. For this reason, an active pull-up circuit (Q509) is used to increase the switching speed of blanking amplifier Q510. The logic 1 to logic 0 transition that is applied to Q510 is also coupled through C509 to the base of Q509, momentarily turning it on. When Q509 turns on, it momentarily shunts resistor R535. This lowers the load impedance to Q510 which immediately turns it off. This circuit makes sure the CRT blanks and unblanks quickly, especially at fast sweep speeds.

CRT PASSIVE CONTROLS

Filament voltage of 6.3 volts AC is connected to the cathode of the CRT. The cathode is also connected through diode ZD601 to -1000 volts. This negative potential accelerates the electrons toward the positive anode (face) of the CRT. Diode ZD601 limits the cathode potential to approximately -930 volts. Since first control grid G1 is also tied to -1000 volts, through Intensity control R605, the diode insures that the cathode is never more positive than the grid. The remaining CRT controls shape and regulate the electron beam as it is accelerated toward the display screen.

POWER SUPPLY

All power supplies are derived from the power transformer. Six different primary winding configurations can be selected with switch SW1, to accommodate various line voltages. Six different secondary windings produce the necessary AC voltages to the power supply.

6.3 VOLTS AC

As mentioned in the previous section, a separate 6.3 volt secondary transformer winding supplies heater current to the CRT. The -1000 volts DC is also tied to this line for CRT electron acceleration.

+3000 VOLTS

A half-wave voltage tripler comprised of diodes D709, D710, and D711, and capacitors C709, C710, and C711 provide +3000 volts from the 900-volt transformer winding. This is filtered by resistor R708 and capacitor C708, and connected to the CRT anode. Resistors R725 load the winding.

-1000 VOLTS

The -1000 volt supply is also provided from the 900-volt transformer winding through half-wave rectifier D712, D713, and D714. The -1000 volt supply, and indirectly the +3000 volt supply, is regulated by a DC controlled AC diode bridge (D705, D706, D707, and D708). The DC control voltage is developed across transistor Q702 and is limited to 280 volts by diodes ZD702, ZD703, and ZD704. Base control current for Q702 is coupled from the 195-volt supply through resistors R703 and R707. This current also flows through diode D701 to the emitter of emitter-follower Q701. The -1000 volt supply is coupled back to the base of Q701. Thus, any variation in the -1000 volt supply alters the current through D701 and, as a result, the base current of Q702. In turn, this determines the voltage across the diode bridge between ground and +280 volts. High Voltage Adjust R703 sets the base-collector bias and thus the -1000 volt level.

6 VOLTS AC

A 6.3-volt transformer winding supplies current for pilot lamp PL1 through resistor R609, and graticule lamps PL2 and PL3 through resistor R607. GRATICULE control R608 controls the lamp current.

+90 AND +195 VOLTS

Full-wave rectifier diodes, D715 and D716, rectify the 200 volts AC from the power transformer. This is filtered to

produce the 195-volt supply used in the horizontal deflection amplifier and the -1000 volt regulator. A second filter divides the 200-volt source down to 90 volts for the vertical deflection amplifier and the blanking amplifier.

±15 VOLTS

Diodes D717, D718, and D719, D720, comprise two full-wave rectifiers that produce positive and negative 21 volts DC from the power transformer. These are filtered and then coupled through pass transistors Q703 and Q704. Transistor base voltage is set by the dual polarity tracking regulator IC701, and feedback current to the regulator is limited by resistors R711 and R712. This limiting in turn limits the supply current for short-circuit protection.

Voltage adjust control R722 calibrates the -15 volt line and, through the regulator, the +15 volt line. Capacitors C712 and C713 reduce load transients.

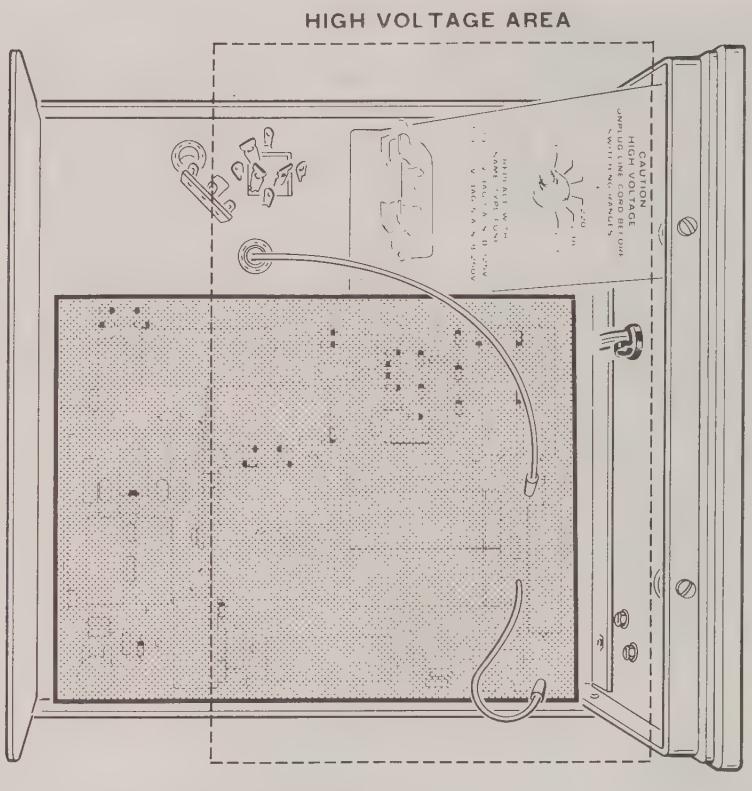
±5 VOLTS

Full-wave rectifier diodes; D721, D722, D723, and D724; produce a positive and negative 8 volts DC from the power transformer. Capacitors C721 and C723 filter the raw DC, while transistors Q706 and Q708 serve as pass elements. Their outputs are limited to 5 volts by zener diodes ZD725 and ZD726, which are connected to the base of each transistor. In the positive 5-volt supply, resistor R716 sets the base-emitter current of Q705 to shut down the supply above approximately 400 mA. Resistor R718 and transistor Q707 limit the -5 volt supply to approximately 100 mA. Capacitors C720 and C722 reduce load transients.

The line sync trigger signal is coupled from the 8-volt transformer secondary winding through resistor R715 to the Trig Select switch.

1V P-P CIRCUIT

An oscillator circuit comprised of IC102A, IC102D, and their associated components generate an output of approximately 1000 Hz. This is coupled through IC102C to the base of transistor switch Q123. Ferrite bead FB103 isolates oscillator noise from the 5-volt supply. Pull-up resistor R206 insures proper voltage levels for switch operation. When Q123 is turned off, a precise 1-volt level is connected to the output. Resistors R207, R208, and R209 set the output level. When Q123 is turned on, it grounds the output.


HIGH VOLTAGE AREA
CAUTION
HIGH VOLTAGE
UNPLUG LINE CORD BEFORE

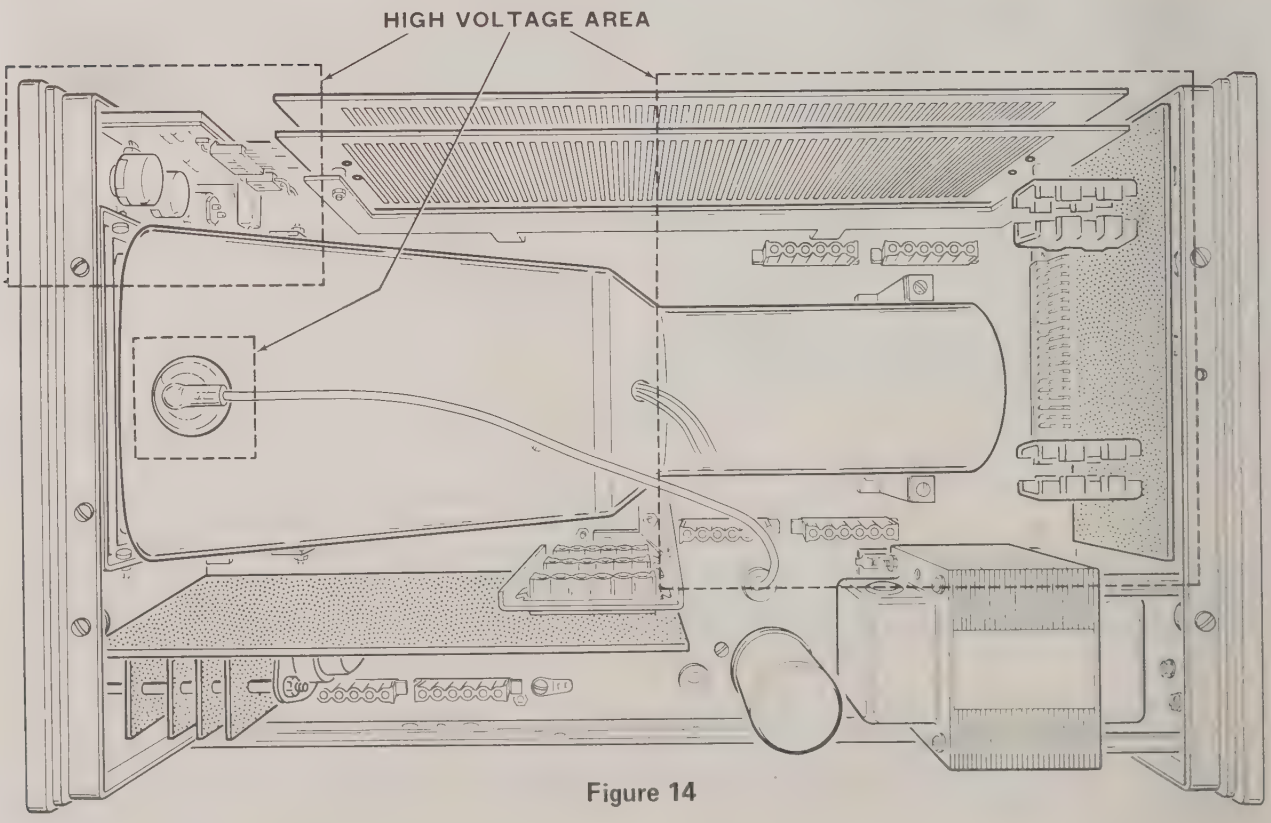

HIGH VOLTAGE AREA

Figure 14

CALIBRATION

This section of the Manual is divided into two parts: "Initial Calibration" and "Touch-Up Adjustments." The "Initial Calibration" must always be performed after the Oscilloscope has been serviced or parts have been replaced. The "Touch-Up Adjustments" must always be performed after the "Initial Calibration" and any time you doubt the accuracy of your calibrated Oscilloscope.

INITIAL CALIBRATION

The following equipment is needed to calibrate your Oscilloscope:

- VTVM – Accurate to within 1% at 15 volts DC.
- Heathkit Oscilloscope Calibrator – OR – A Square Wave Generator capable of producing 1 kHz to 1 MHz signals, with up to 5 volts output rise time < 5 nS and overshoot $< 1\%$.
- A 1000 Hz Square Wave Voltage Calibrator (1 to 100 volt output) is also recommended, but not necessary; accurate in amplitude to 1% at 1 volt; accurate in frequency to 1%.

Controls and adjustments associated with channel Y1 are identified as Y1, CH1, or a "-1" following the circuit component number, such as R119-1. Channel Y2 controls and adjustments are identified as Y2, CH2, or a "-2" following the circuit component number. Use the plastic alignment tool supplied with this kit to reach and make the adjustments.

If you do not obtain the proper results, turn the Oscilloscope off, refer to the "In Case of Difficulty" section of the Manual, and correct any difficulties before proceeding.

LINE VOLTAGE

Turn off the Oscilloscope and disconnect the line cord plug from the AC power source.

Loosen the knurled knob on each side of the chassis and remove the top and bottom covers. Be careful not to touch any of the circuitry when you move the Oscilloscope around for various adjustments. Dangerous voltages are present.

WARNING: Observe the safety precautions that pertain to your particular voltmeter when you measure the power line voltage in the following step.

NOTE: With the covers removed from the Oscilloscope, some signal drift will occur. This is due to the thermal drift of the sensitive vertical preamplifier circuits.

1. Measure the line voltage.
2. Set the LINE VOLTAGE switch (S1) to the nearest appropriate voltage setting.
3. Connect the line cord plug to the AC power source.
4. Turn the GRATICULE control (R608/S601) clockwise to turn on the Oscilloscope. The power indicator lamp should light.
5. Allow the Oscilloscope to warm up for a few minutes before you proceed.

WARNING: When the line cord is connected to an AC outlet, AC voltage will be present at several places on the chassis and on the control circuit board. When the Oscilloscope is turned on, high voltage DC will also be present. Be careful that you do not contact this voltage or an electrical shock will result. See Figure 14.

VOLTAGE ADJUSTMENTS

Refer to Parts A and B of Figure 15 (fold-out from Page 37) for the following steps.

1. Adjust your voltmeter to measure +15 volts DC.

2. Connect the negative voltmeter lead to the Oscilloscope chassis.

3. Measure the voltage at pin 6 (marked +15) of connector F on the power supply circuit board. Adjust the LV ADJ control (R722, on the power supply circuit board) for a +15 volt meter indication.

4. Adjust your voltmeter to measure -1500 volts DC.

5. Measure the voltage at pin 6 (with the violet wire) of connector H on the power supply circuit board. Adjust the HV ADJ control (R705, on the power supply circuit board) for −1000 volts DC (±10 volts).

BEAM ADJUSTMENTS

1. Set the indicated front panel controls as follows:

Y1:	
INPUT switch (AC-GND-DC)	GND
VOLTS/CM	20 mV
VARIABLE	Fully clockwise (CAL)
POSITION	Fully counterclockwise (OFF)
Y2:	
INPUT switch (AC-GND-DC)	GND
VOLTS/CM	20 mV
VOLTS VARIABLE	Fully clockwise (CAL)
POSITION	Center trace on screen
VARIABLE – X5	Fully clockwise (CAL) and pushed in.
TRIGGER SELECT	Y1, +
LEVEL	AUTO
TRIGGER MODE	AC
TIME/CM	EXT
HORIZ POS	Center spot on screen.

2. Turn the INTENSITY control* counterclockwise to decrease the brightness of the spot. Readjust this control as necessary to keep the spot small when you make the following focus and astigmatism adjustments.

3. Alternately adjust the FOCUS control and the ASTIGMATISM control (R569, a screwdriver adjustment through the rear panel) to obtain the smallest possible round spot on the CRT screen.

4. Set the indicated front panel controls as follows:

Y2 POSITION	Fully counterclockwise (OFF)
TIME/CM	.1 mS
Y1 POSITION	Center trace on screen

5. Readjust the HORIZ POS (Horizontal Position) control to center the trace on the screen.

6. Adjust the TRACE ROTATION control (R464, on the time base circuit board) to position the trace parallel to the horizontal graticule lines.

VERTICAL AMPLIFIER BALANCE

Channel Y1: Perform the following numbered steps (1-15). Adjust only the controls associated with channel Y1.

NOTE: If you are unable to obtain a proper DC balance in the following steps, refer to the "Special Note" (left column, Page 29).

1. Adjust the POSITION control to place the trace on the horizontal centerline.

2. Turn the VARIABLE control fully counterclockwise. The trace may move off screen.

3. Adjust the POSITION control to return the trace to the center horizontal graticule line.

4. Turn the VARIABLE fully clockwise (CAL).

5. Slowly adjust the DC BAL control (R119, a screwdriver adjustment through the front panel) to return the trace to the center horizontal graticule line.

6. Repeat steps 2 through 5 until the trace does not move when you turn the VARIABLE control. Leave the VARIABLE control in the fully clockwise position (CAL). NOTE: See the "Special Note" on the fold-out from this page.

*Refer to Figure 1 in this Manual (fold-out from Page 4) for the circuit component number of any front panel control switch.

7. Turn the VOLTS/CM switch to the 2 mV position.

8. Adjust the POSITION control to place the trace on the center horizontal graticule line.

9. Turn the VOLTS/CM switch to the 1 mV position.

10. Adjust the STEP BAL control (R129, on the vertical circuit board) to return the trace to the center horizontal graticule line.

11. Repeat steps 7 through 10 until the trace does not move when you turn the VOLTS/CM switch from the 2 mV to the 1 mV position.

NOTE: Since the covers are removed, some drifting may be apparent when you place the VOLTS/CM switch in the 1 mV position in the following step. This is caused by air currents through the sensitive circuits.

12. Turn the VOLTS/CM switch to the 1 mV position and repeat steps 1 through 11 until there is no shift (change) in the position of the trace as you turn the VARIABLE control back and forth between fully clockwise and counterclockwise, or as you change the Volts/CM switch position.

13. Turn the POSITION control to the 12 o'clock position.

14. Adjust the COARSE BALANCE control (R150, on the vertical circuit board) to position the trace on the center horizontal graticule line.

15. Turn the POSITION control fully counterclockwise (OFF).

Channel Y2: Perform the previous numbered steps (1-15). Adjust only the controls associated with Channel Y2.

SPECIAL NOTE:
If you cannot balance a particular vertical amplifier (channel Y1 or channel Y2), the components listed below (and associated with the affected channel) should be interchanged. They are listed in the order of greater effect.

Interchange: R124 — with R125.

If you still cannot balance the vertical amplifier;

Interchange: Q102 — with Q103.

If you still cannot balance the vertical amplifier;

Interchange: ZD103 — with ZD104.

If you still cannot balance the amplifier. Lift Q101A/B and turn it 180° and reinstall it.

GEOMETRY ADJUSTMENT

1. Set the indicated front panel controls as follows:

Y1:

INPUT switch	GND
POSITION	Fully counterclockwise (OFF)

Y2:

INPUT switch	AC
VOLTS/CM	2V
POSITION	Center trace on screen
TIME/CM	EXT

2. Connect oscilloscope test cables to the Y1 and Y2 INPUT connector.

3. Connect the Y2 test cable inner lead to connector L4 (line sync) on the time base circuit board.

4. Adjust the HORIZ POS control to center the line.

5. Adjust the Y2 VOLTS/CM switch and the Y2 VARIABLE gain control to obtain a vertical line 6 cm high. NOTE: This line may not be exactly vertical (parallel to the vertical graticule lines).

6. Adjust the FOCUS control to obtain the sharpest line.

7. Position the line first at the right side of the screen and then at the left side of the screen. Notice the bow in the line when it is near each side.

8. Adjust the GEOMETRY control (R568, a screwdriver adjustment through the rear panel) to remove the bow and make the line as straight as possible at each side of the screen. The GEOMETRY control will cause the trace to move. Reposition the trace as necessary. It may also be necessary to readjust the FOCUS, ASTIGMATISM, and GEOMETRY controls several times to obtain optimum results.

9. Disconnect the test cable from connector L4.

10. Set the indicated front panel controls as follows:

Y2:

INPUT switch	GND
POSITION	Center spot on screen

11. Readjust the FOCUS control to obtain the smallest round spot on the CRT.

12. Turn the TIME/CM switch to the .1 μS position.

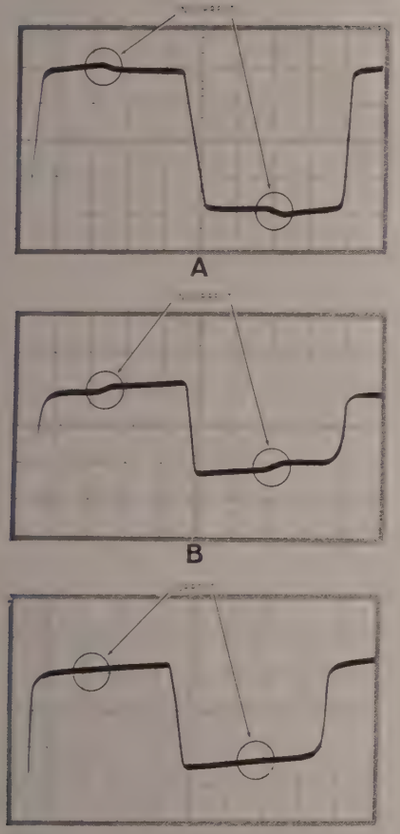


Figure 16

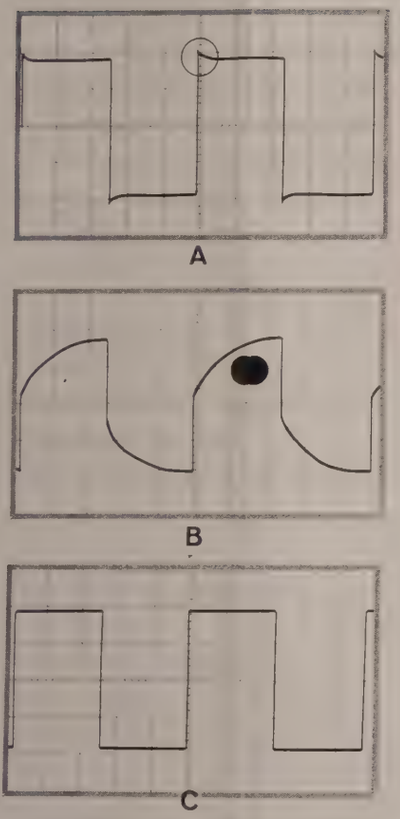


Figure 21

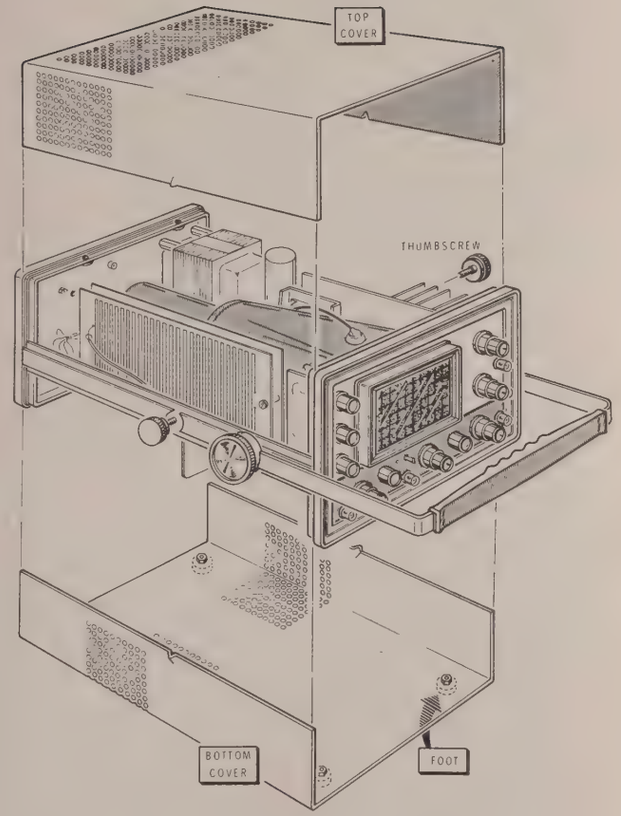


Figure 24

DELAY LINE TERMINATION

1. Set the indicated front panel controls as follows:

   Y1:
   VOLTS/CM 2V
   POSITION Center trace on screen
   INPUT switch AC

   Y2:
   POSITION Fully counterclockwise (OFF)
   HORIZ POS Position the trace to start at the left side of the screen

2. Turn SQUARE WAVE COMPENSATION controls R504 and R505 (on the deflection circuit board) fully clockwise.

3. Connect a 1 MHz, 5-volt square wave signal to the Y1 INPUT connector.

4. Adjust SQUARE WAVE COMPENSATION trimmer capacitors C503 and C504 (on the deflection circuit board) for the roundest leading corner of the waveform (minimum capacitance) as shown in Part B of Figure 21.

5. Adjust the Y1 HF ADJ trimmer capacitor (C126-1, on the vertical circuit board) for the roundest leading corner of the waveform (minimum capacitance).

6. Adjust the DELAY LINE TERMINATION control (R502, on the deflection circuit board) for the straightest top on the waveform. Figure 16 shows the two incorrect extremes of this adjustment (A and B) as well as the correct delay line termination (C). It is normal for the overall waveform amplitude to change as you make this adjustment.

7. Set the Y1 INPUT switch to GND.

8. Disconnect the square wave signal.

VERTICAL AMPLIFIER

1. Set the indicated front panel controls as follows:

   TIME/CM 1 mS
   Y1:
   VOLTS/CM .2V
   POSITION Center trace on screen
   INPUT switch GND

   Y2:
   VOLTS/CM .2V
   POSITION Fully counterclockwise (OFF)
   INPUT switch GND

2. Channel Y1: Perform the following lettered steps (A-G). Adjust only the controls marked Y1 or associated with channel Y1.

   A. Adjust the POSITION control to place the trace on the horizontal centerline.

   B. Make sure the VARIABLE control (R128) is fully clockwise (CAL) position.

   C. Set the INPUT switch to AC.

   D. Connect the test cable inner lead to the 1V P-P connector on the front panel. This connection can be easily made at the rear of the connector from the inside of the front panel. Connect the shield lead to the chassis. NOTE: A Square Wave Voltage Calibrator may be used instead of the 1V P-P output from the Oscilloscope.

   E. Adjust the CAL control (R157, on the vertical circuit board) and the POSITION control for a waveform exactly 5 cm high.

   F. Disconnect the test leads from the 1V P-P connector.

   G. Turn the POSITION control fully counterclockwise (OFF).

3. Channel Y2: Turn the TRIGGER SELECT switch to the Y2, + position. Then perform the previous lettered steps (A-G). Adjust only the controls marked Y2 or associated with channel Y2.

TRIGGER

1. Set the Y1 and Y2 INPUT switch to GND.
2. Adjust the Y1 and Y2 position controls to place both traces on the horizontal centerline.
3. Adjust your voltmeter to measure +1.5 volts DC.
4. Measure the voltage at pin 6 (CH1 TR OUT – Channel 1 Trigger Output) of connector B on the vertical circuit board. Adjust the Y1 DC TRIG ADJ control (R176-1, on the vertical circuit board) for zero volts.
5. Measure the voltage at pin 2 (CH2 TR OUT) of connector C on the vertical circuit board. Adjust the Y2 DC TRIG ADJ control (R176-2, on the vertical circuit board) for zero volts.
6. Disconnect the voltmeter.

HORIZONTAL AMPLIFIER

1. Set the indicated front panel controls as follows:

TIME/CM	1 mS
Y1: INPUT switch	DC
VOLTS/CM	.5V
POSITION	Center trace on screen
Y2: POSITION	Fully counterclockwise (OFF)
TRIGGER SELECT	LINE, +

2. Connect the Y1 test cable inner lead to pin 1 (RAMP OUT) of connector J on the time base circuit board.
3. Turn the H GAIN control (R549, on the deflection circuit board) to the center of rotation.
4. Adjust the SWEEP LENGTH control (R437, on the time base circuit board) and the Y1 POSITION control for a diagonal trace 3-1/2 cm high as shown in Figure 17.
5. Set the Y1 INPUT switch to GND.
6. Disconnect the Y1 test cable from the RAMP OUT pin.
7. Adjust the H GAIN control (R549, on the deflection circuit board) and the HORIZ POS control for a trace exactly 10 cm long. NOTE: if you are unable to obtain a trace 10 cm long, leave the H GAIN control fully counterclockwise. Then adjust the SWEEP LENGTH control (R437, on the time base circuit board) for a trace exactly 10 cm long.
8. Turn the HORIZ POS control to move the right-hand end of the trace 1 cm to the left.
9. Adjust the SWEEP LENGTH control (R437, on the time base circuit board) to move the right-hand end of the trace back to the right 1 cm.
10. Readjust the HORIZ POS control so the left-hand edge of the trace starts at the left-hand graticule line.

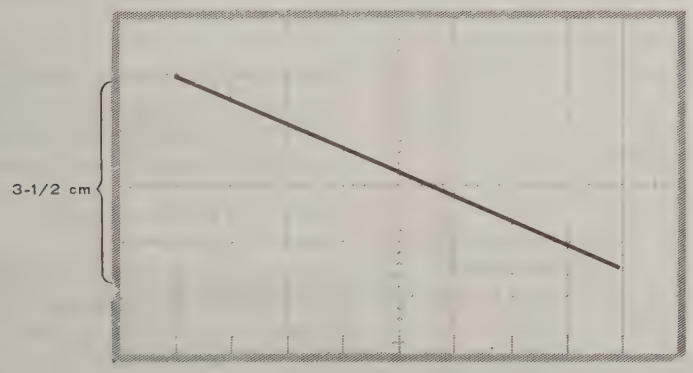


Figure 17

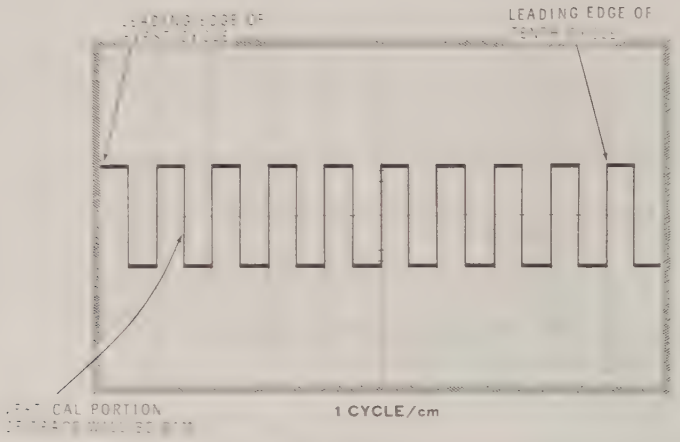


Figure 18

SWEEP

1. Set the indicated front panel controls as follows:

Y1 INPUT switch	AC
TRIGGER SELECT	Y1, +
TIME/CM	1 mS
VARIABLE	CAL

2. Connect a 1000 Hz square wave signal to the Y1 INPUT connector. Adjust the signal amplitude for a 2-4 cm vertical display.

3. Carefully adjust the SWEEP CAL control (R423, on the time base circuit board) and the HORIZ POS control for exactly 10 cycles in 10 centimeters (1 cycle per centimeter) as shown in Figure 18. Use the leading edge of the first and tenth cycle for this adjustment.

4. Pull out on the VARIABLE – X5 switch.

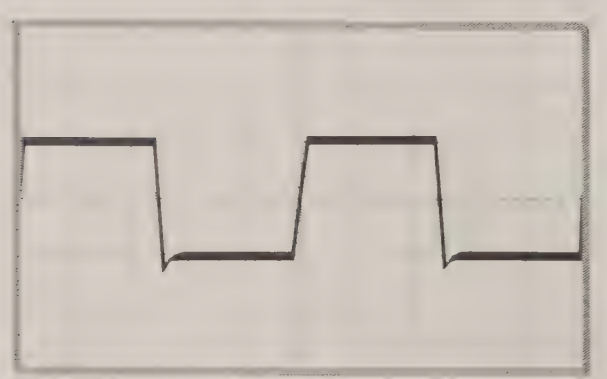


Figure 19

5. Adjust the X5 CAL control (R539, on the deflection circuit board) and the HORIZ POS control for exactly 2 cycles in 10 centimeters as shown in Figure 19. When you make this adjustment, place the leading edge of the first cycle on the left-hand graticule line and the leading edge of the second cycle on the center graticule line.

6. Push in on the VARIABLE – X5 switch.

7. Disconnect the square wave signal.

8. Place the Y1 INPUT switch in the GND position.

X-Y

1. Turn the Y1 VOLTS/CM switch to the .2V position.

2. Turn the TIME/CM switch to the X-Y position.

3. Turn the TRIG SELECT (Trigger Select) switch to Y2, +.

4. Adjust the Y1 and Y2 POSITION controls to center the spot on the graticule. Adjust the HORIZ POS control so the Y1 POSITION control will move the spot off the screen in both directions.

5. Set the Y1 INPUT switch to AC.

6. Connect the Y1 test cable inner lead to the 1V P-P connector on the front panel. Connect the shield lead to the chassis. NOTE: A square wave voltage calibrator may be used instead of the oscilloscope 1V P-P output.

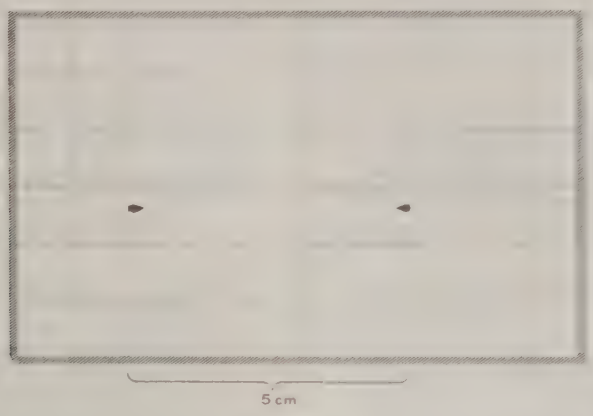


Figure 20

7. Adjust the X-Y CAL control (R170, on the vertical circuit board) to place the two dots exactly 5 cm apart as shown in Figure 20.

8. Disconnect the Y1 test cable from the 1V P-P connector.

ATTENUATOR COMPENSATION

The purpose of the following adjustments is to obtain the proper amount of high frequency compensation for each position of the VOLTS/CM switch. Parts A, B, and C of Figure 21 (fold-out from Page 28) show the conditions of too much compensation, too little compensation, and the correct amount of compensation respectively. Use the plastic alignment tool supplied with this kit to make the following adjustments.

1. Set the indicated front panel controls as follows:

TIME/CM	.2 mS
TRIGGER SELECT	Y1, +
Y1:	
INPUT switch	AC
VARIABLE	Fully clockwise (CAL)
VOLTS/CM	50 mV
POSITION	Center trace on screen
Y2:	
INPUT switch	AC
VARIABLE	Fully clockwise (CAL)
VOLTS/CM	50 mV
POSITION	Fully counterclockwise (OFF)
HORIZ POS	Center trace on screen

2. Channel Y1: Perform the following lettered steps (A-I). Adjust only the controls that are marked Y1 or associated with channel Y1.

   A. Adjust the POSITION control to place the trace on the horizontal centerline.

   B. Connect a 1000 Hz square wave signal to the INPUT connector. Adjust the signal amplitude of this signal for a trace 4 cm high. Readjust the amplitude of this signal as necessary in the following steps to maintain a suitable size trace (1-4 cm).

   C. Adjust trimmer capacitor C113 (÷ 10) to obtain the proper amount of compensation.

   D. Turn the VOLTS/CM switch to the .5V position.

   E. Adjust trimmer capacitor C108 (÷ 100) to obtain the proper amount of compensation.

   F. Turn the VOLTS/CM switch to the 5V position.

   G. Adjust trimmer capacitor C104 (÷ 1000) to obtain the proper amount of compensation.

   H. Disconnect the square wave signal.

   I. Turn the POSITION control fully counterclockwise (OFF).

3. Channel Y2: Turn the TRIGGER SELECT switch to Y2, +. Then perform the previous lettered steps (A-I). Adjust only the controls that are marked Y2 or associated with channel Y2.

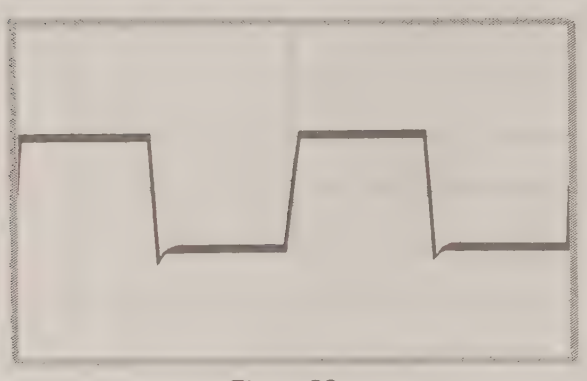


Figure 22

SQUARE WAVE COMPENSATION

Square Wave Compensation controls R504, R505, C503, and C504 will be adjusted in the following steps to obtain the optimum square wave response and fastest rise time without excessive overshoot, as shown in Figure 22. The controls will first be adjusted to minimum. Then each one will be adjusted, in sequence, to "fill in" the leading corner of the square wave to obtain the squarest corner and flattest top. Each control "bends" the top of the square wave at a different spot. Figure 23 shows the approximate portion of the waveform affected by each control. Some of the controls may require considerable adjustment (rotation) to obtain the best response, while others may require little or no adjustment. Disregard the bottom portion of the waveform when you make the adjustments.

1. Set the indicated front panel controls as follows:

TIME/CM	2 μS
TRIGGER SELECT	Y1, +
Y1:	
INPUT switch	AC
VARIABLE	Fully clockwise (CAL)
VOLTS/CM	1V
POSITION	Center trace on screen
Y2:	
INPUT switch	GND
VARIABLE	Fully clockwise (CAL)
VOLTS/CM	1V
POSITION	Fully counterclockwise (OFF)

2. Connect a 100 kHz square wave signal to the Y1 INPUT connector.

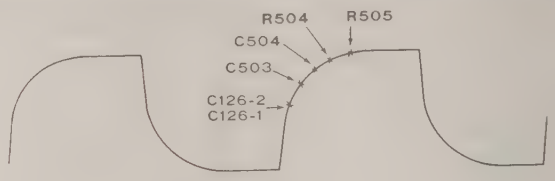


Figure 23

3. Adjust SQUARE WAVE COMPENSATION control R504 for the straightest top along the first 2/3 of the square wave. It may be helpful to imagine a straight line along the top of the waveform. Adjust the control counterclockwise only enough to obtain the best fit with the imaginary line. If the adjustment is overcompensated, the top of the waveform may bow upward.

4. Disconnect the 100 kHz square wave signal.

5. Connect a 1 MHz square wave signal to the Y1 INPUT connector.

6. Turn the TIME/CM switch to the .2 μS position.

7. Rotate SQUARE WAVE COMPENSATION CONTROL R505 through its range. Notice that a hump moves up the leading edge and along the top of the waveform. Adjust control R505 so the hump is in the leading corner (but not on top) of the waveform.

8. Adjust trimmer capacitors C503, C504, C126-1 consecutively for a waveform with the squarest corner, flattest top, and without overshoot.

9. Readjust R504, R505, C503, C504, and C126-1 consecutively until no further improvement is possible.

10. Set the indicated front panel controls as follows:

Y1:	
INPUT switch	GND
POSITION	Fully counterclockwise (OFF)
Y2:	
INPUT switch	AC
POSITION	Center trace on screen
TRIGGER SELECT	Y2, +

11. Disconnect the 1 MHz square wave signal from the Y1 INPUT connector.

12. Connect a 1 MHz square wave signal to the Y2 INPUT connector.

13. Adjust the Y2 HF ADJ trimmer capacitor (C126-2, on the vertical circuit board) for the proper amount of compensation. NOTE: Due to the various component tolerances, the square wave response of Channel Y1 may not be exactly the same as Channel Y2.

14. Disconnect the 1 MHz square wave signal.

15. Turn the Y2 POSITION control fully counterclockwise (OFF).

This completes the "Calibration" of you Oscilloscope unless you have a low capacitance (X10) probe. Proceed to "Touch Up Adjustments."

LOW CAPACITANCE PROBE

Perform the following steps only if you have a low capacitance (X 10) probe that will compensate to approximately 40 pF (35-47 pF).

Probe Compensation and Amplifier Equalization

This adjustment procedure equalizes the input capacitance of both vertical amplifiers so a low capacitance probe can be used on either channel without the need to recompensate. If you have two probes, set one of them aside temporarily. Perform the following adjustments using the one probe. Then connect the other probe and adjust only the probe trimmer for the proper amount of compensation.

1. Set the indicated front panel controls as follows:

Y1:

VOLTS/CM	20 mV
POSITION	Center trace on screen
INPUT switch	AC
TIME/CM	.2 mS
TRIGGER SELECT	Y1, +

2. Connect the low capacitance probe to the Y1 INPUT connector.

3. Connect the probe end to a 1000 Hz square wave signal. Adjust the amplitude of this signal for a 4-5 cm display.

4. Adjust the probe trimmer for the proper amount of compensation as shown in Part C of Figure 21. Do not try to obtain the ultimate adjustment at this time.

NOTE: The trimmer capacitors called out in the following steps are on the vertical circuit board.

5. Adjust the Y1 input trimmer capacitor C115-1 (÷ 1) to obtain the maximum amount of overshoot on the leading edge of the waveform as shown in Part A of Figure 21. This adjustment sets the Y1 input trimmer capacitor at minimum capacitance.

6. Readjust the probe trimmer for the correct amount of compensation.

7. Disconnect the probe from the Y1 INPUT connector and connect it to the Y2 INPUT connector.

8. Set the indicated front panel controls as follows:

Y1:

POSITION	Fully counterclockwise (OFF)

Y2:

POSITION	Center trace on screen
VOLTS/CM	20 mV
INPUT switch	AC
TRIGGER SELECT	Y2, +

9. Adjust Y2 input trimmer capacitor C115-2 (÷ 1) for the correct amount of compensation. If you obtain proper compensation, disregard the following lettered steps and proceed to the next step. If you cannot obtain proper compensation, perform the following lettered steps.

   A. Adjust Y2 input trimmer capacitor C115-2 (÷1) for the maximum amount of overshoot on the leading edge of the waveform as shown in Part A of Figure 21. This adjustment sets the Y2 input capacitor to minimum capacitance.

   B. Adjust the probe trimmer for the proper amount of compensation.

   C. Disconnect the probe from the Y2 INPUT connector and connect it to the Y1 INPUT connector.

   D. Set the indicated front panel controls as follows:

Y1 POSITION	Center trace on screen
Y2 POSITION	Fully counterclockwise (OFF)
TRIGGER SELECT	Y1, +

   E. Adjust the Y1 input trimmer capacitor C115-1 (÷ 1) for the proper amount of compensation.

10. Set the indicated front panel controls as follows:

Y1:

POSITION	Center trace on screen
VOLTS/CM	50 mV

Y2:

POSITION	Fully counterclockwise (OFF)
VOLTS/CM	50 mV
TRIGGER SELECT	Y1, +

11. Connect the probe to the Y1 INPUT connector.

Input Compensation

NOTE: Readjust the 1000 Hz square wave amplitude as necessary throughout the following procedure to increase the display amplitude.

1. Channel Y1: Perform the following lettered steps (A-K). Adjust only the controls and trimmer capacitors marked Y1 or associated with Channel Y1.

   A. Adjust the POSITION control to put the trace in the center of the screen.

   B. Adjust trimmer capacitor C111 (÷ 10) for the proper amount of compensation.

   C. Turn the VOLTS/CM switch to the .5V position.

   D. Adjust trimmer capacitor C106 (÷ 100) for the proper amount of compensation.

   E. Turn the VOLTS/CM switch to the 5V position.

   F. Connect a test lead to the EXT TRIGGER connector.

   G. Connect the test leads of this cable between a 1000 Hz square wave signal and ground.

   H. Turn the TRIGGER SELECT switch to the EXT, + position.

   I. Adjust trimmer capacitor C102 (÷ 1000) for the proper amount of compensation. Examine this display carefully as it may be quite small.

   J. Turn the POSITION control fully counterclockwise (OFF).

   K. Turn the TRIGGER SELECT switch to Y2, +, and decrease the amplitude of the 1000 Hz square wave signal.

2. Disconnect the probe from the Y1 INPUT connector and connect it to the Y2 INPUT connector.

3. Channel Y2: Perform the previous lettered steps (A-K). Adjust only the controls and trimmer capacitors marked Y2 or associated with Channel Y2.

4. Disconnect the square wave signal from the Oscilloscope.

5. Disconnect the Oscilloscope test cable from the EXT TRIGGER connector.

6. Set the indicated front panel controls as follows:

Y1:

INPUT switch	GND
POSITION	Center trace on screen

Y2:

INPUT switch	GND
POSITION	Fully counterclockwise (OFF)

7. Turn off the Oscilloscope and disconnect the line cord plug from the AC power source.

8. Position the top and bottom covers on the Oscilloscope as shown in Figure 24 (fold-out from Page 30). Be sure the ventilation holes in the covers are toward the back of the Oscilloscope and the covers are seated in the grooves in the side rails. Then tighten the two thumbscrews to hold the covers in place.

Proceed to "Touch-up Adjustments."

TOUCH-UP ADJUSTMENTS

This section of the Manual deals with the final or touch-up adjustments that insure the accuracy of your Oscilloscope. Any time you perform the "Initial Calibration," operate the Oscilloscope for at least 48 hours, and then perform all of the following touch-up adjustments. However, any time you doubt the accuracy of a particular circuit within your calibrated Oscilloscope, make only the appropriate touch-up adjustment.

Allow the Oscilloscope to warm up for at least three hours with the covers on and with the Oscilloscope setting in its normal operating position. Do not stand it on the rear panel to make the touch-up adjustments. Keep it in the normal operating position.

To insure that the adjustments are made under actual operating conditions, remove the appropriate cover only long enough to make each adjustment. Replace the cover immediately after you make each adjustment and allow 5 minutes for the Oscilloscope to stabilize. Then recheck the adjustment.

If you have replaced components or serviced the Oscilloscope, you must perform the "Initial Calibration" before you make touch-up adjustments.

Touch-Up Sweep Adjustment (time base calibration) – Carefully perform the "Sweep" calibration steps (1-8) on Page 32. NOTE: The sweep calibration is affected when the Voltage, Geometry, and Horizontal Amplifier are readjusted.

Touch-Up Vertical Amplifier Gain Adjustment – Carefully perform the "Vertical Amplifier" calibration steps (1-6) on Page 30. NOTE: The vertical calibration is affected when the Voltage, Geometry, and Delay Line Termination are readjusted.

Touch-Up Trigger Adjustment – Carefully perform the "Trigger" calibration steps (1-6) on Page 31. This adjustment is not affected by other adjustments.

Touch-Up X-Y Adjustment – Carefully perform the "X-Y" calibration steps (1-8) on Page 32. NOTE: The X-Y calibration is affected when the Y1 vertical amplifier and horizontal gain are readjusted.

Touch-Up Sweep Length Adjustment – The SWEEP LENGTH control (R437, on the time base circuit board) can be readjusted as desired (usually for a 11 cm trace) without affecting other adjustments.

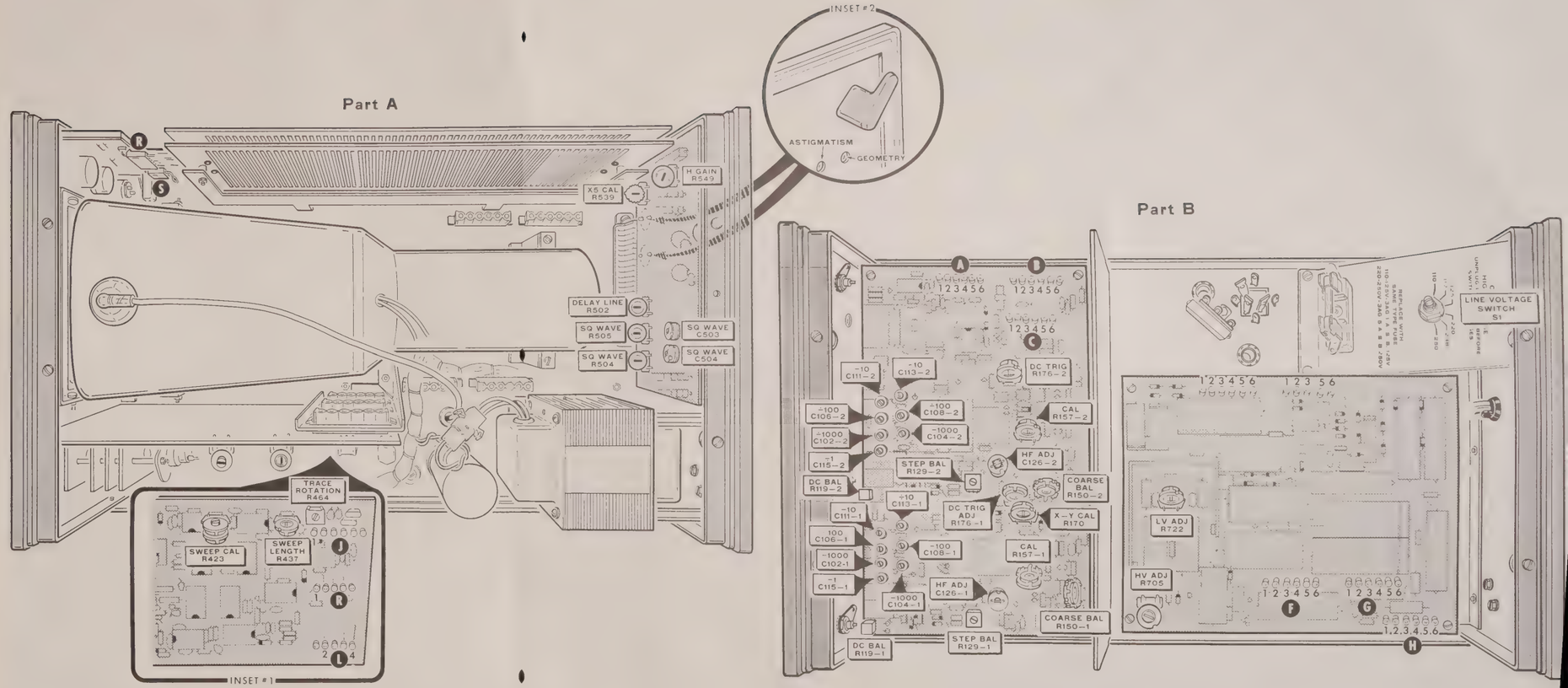


Figure 15

TROUBLESHOOTING

The troubleshooting information for your Oscilloscope is presented in a series of test charts. If you know that a problem exists in a particular circuit, proceed to the test chart that covers that circuit. However, if your Oscilloscope does not operate for an unknown reason, proceed to the section entitled "Locating the Problem." Read the following paragraphs carefully before you begin troubleshooting.

TROUBLESHOOTING PRECAUTIONS AND NOTES

WARNING: The full AC line voltage and high voltage DC is present at several points in the Oscilloscope. Be careful to avoid electrical shock when working on the Oscilloscope.

- Be cautious when testing transistors and integrated circuits. Although they have almost unlimited life when used properly, they are much more vulnerable to damage from excessive voltage and current than other circuit components.

- Be careful so you do not short any terminals to ground when you make voltage measurements. If the probe should slip, for example, and short out a bias or voltage supply point, it may damage one or more components.

- Do not remove any components or circuit boards while the Oscilloscope is turned on.

- Always discharge the power supply as directed in "Discharging The Power Supply" on Page 36 before removing or installing circuit boards.

- When you make repairs to the Oscilloscope, make sure you eliminate the cause as well as the effect of the trouble. If, for example, you should find a damaged resistor, be sure you find out what (wiring error, etc.) caused the resistor to become damaged. If the cause is not eliminated, the replacement resistor may also become damaged when the Oscilloscope is put back into operation.

- Refer to the "X-Ray Views," "Chassis Photographs," "Component Charts," and the "Schematic Diagram" to locate the various components.

- Use a high impedance voltmeter to make the specified measurements in this section. Use a high voltage probe to measure the +3000 volt supply.

- If you suspect that a transistor is defective, first measure the base-to-emitter voltage (Vbe). This voltage is normally between .6 and .8 volts. If the voltage is above this range, the transistor is open. If the voltage is 0 volts, the transistor may be shorted or a base-to-emitter short exists (possibly on the foil side of the circuit board).

- The following symbols and procedures are used in the troubleshooting charts:

YES — Follow the "YES" arrow when you obtain the proper measurement or condition.

NO — Follow the "NO" arrow when you do not obtain the proper measurement or condition.

≈ — This symbol, "APPROXIMATELY EQUAL TO," before a voltage measurement indicates that this voltage may vary as much as ±20%.

REPEAT TEST #1

This means to repeat a particular test after a problem has been located and corrected.

- All voltages given in the troubleshooting charts were taken with a nominal line voltage of 117 VAC.
- Components are listed in the order in which failure or a problem is most likely to occur.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of the Manual. Your Warranty is located inside the front cover.

DISCHARGING THE POWER SUPPLY

The following procedure explains how to discharge the various Oscilloscope power supplies. Perform this procedure before you remove or install the CRT, the deflection circuit board, or the control circuit board. Wait one minute after the power is turned off to allow the power supplies to discharge before you remove or install the vertical circuit board, the time base circuit board, or the power supply circuit board. Failure to properly discharge the power supply may cause electrical shock, may damage circuit components, or both.

If you do not already have the 10 MΩ, 1-watt resistor-alligator clip assembly shown in Figure 25, prepare it as shown.

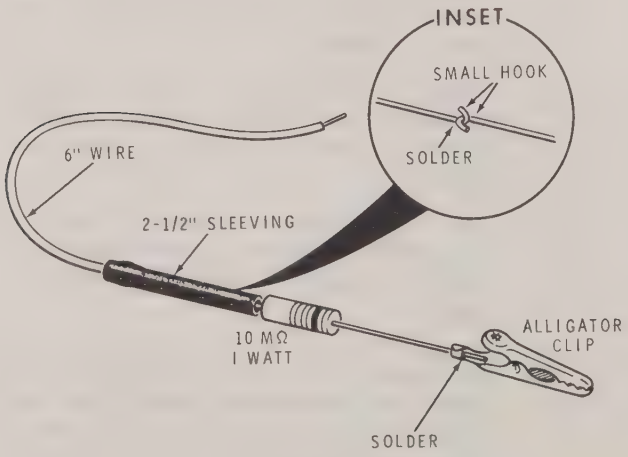


Figure 25

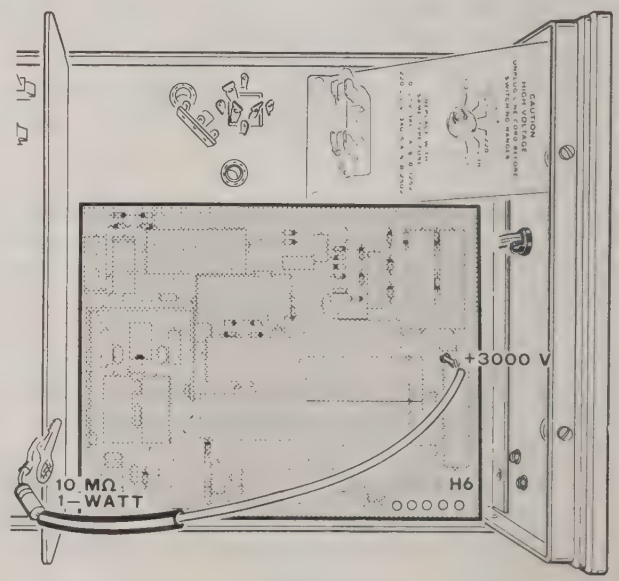
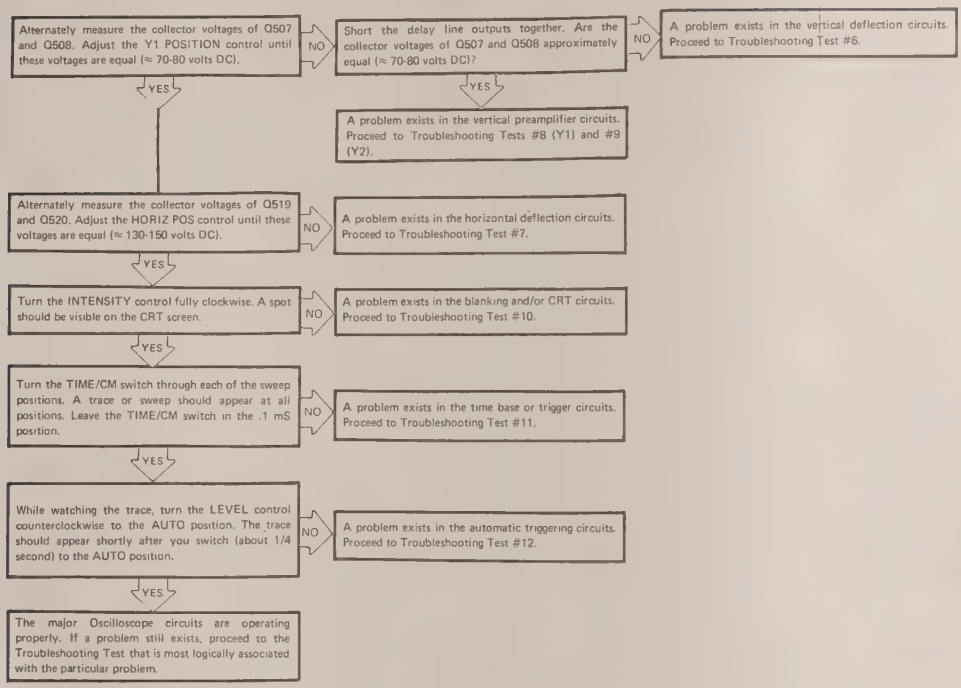


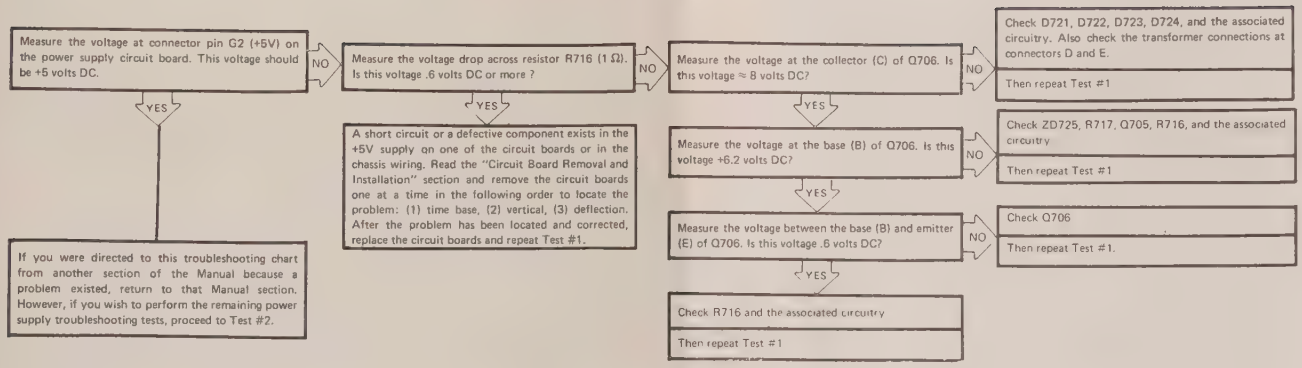
Figure 26

TROUBLE LOCATOR CHART

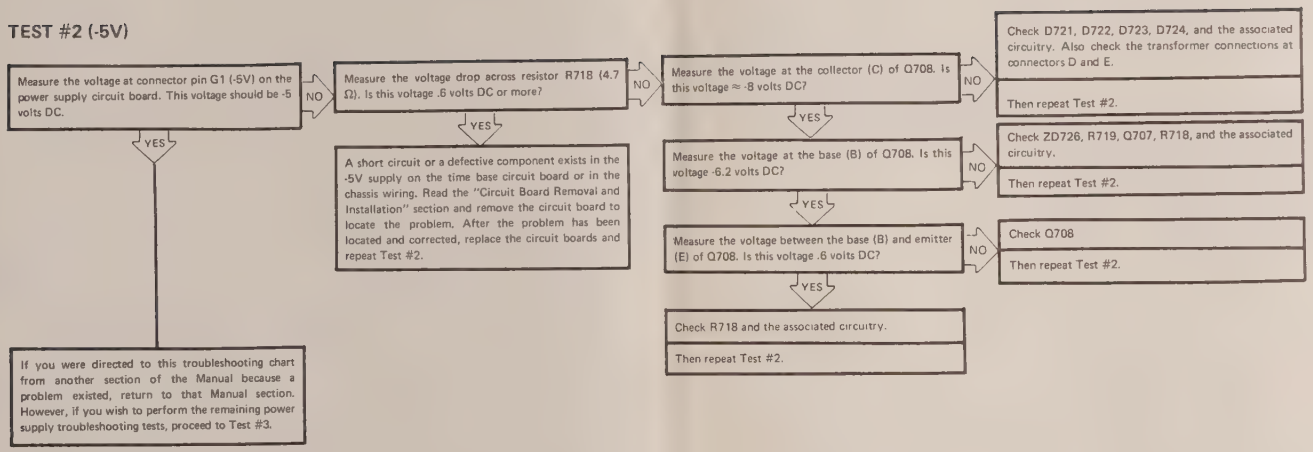

Alternately measure the collector voltages of Q507 and Q508. Adjust the Y1 POSITION control until these voltages are equal (≈ 70-80 volts DC).
NO
Short the delay line outputs together. Are the collector voltages of Q507 and Q508 approximately equal (≈ 70-80 volts DC)?
NO
A problem exists in the vertical deflection circuits. Proceed to Troubleshooting Test #6.
YES
A problem exists in the vertical preamplifier circuits. Proceed to Troubleshooting Tests #8 (Y1) and #9 (Y2).
YES
Alternately measure the collector voltages of Q519 and Q520. Adjust the HORIZ POS control until these voltages are equal (≈ 130-150 volts DC).
NO
A problem exists in the horizontal deflection circuits. Proceed to Troubleshooting Test #7.
YES
Turn the INTENSITY control fully clockwise. A spot should be visible on the CRT screen.
NO
A problem exists in the blanking and/or CRT circuits. Proceed to Troubleshooting Test #10.
YES
Turn the TIME/CM switch through each of the sweep positions. A trace or sweep should appear at all positions. Leave the TIME/CM switch in the .1 mS position.
NO
A problem exists in the time base or trigger circuits. Proceed to Troubleshooting Test #11.
YES
While watching the trace, turn the LEVEL control counterclockwise to the AUTO position. The trace should appear shortly after you switch (about 1/4 second) to the AUTO position.
NO
A problem exists in the automatic triggering circuits. Proceed to Troubleshooting Test #12.
YES
The major Oscilloscope circuits are operating properly. If a problem still exists, proceed to the Troubleshooting Test that is most logically associated with the particular problem.

tical deflection circuits.
Test #6.

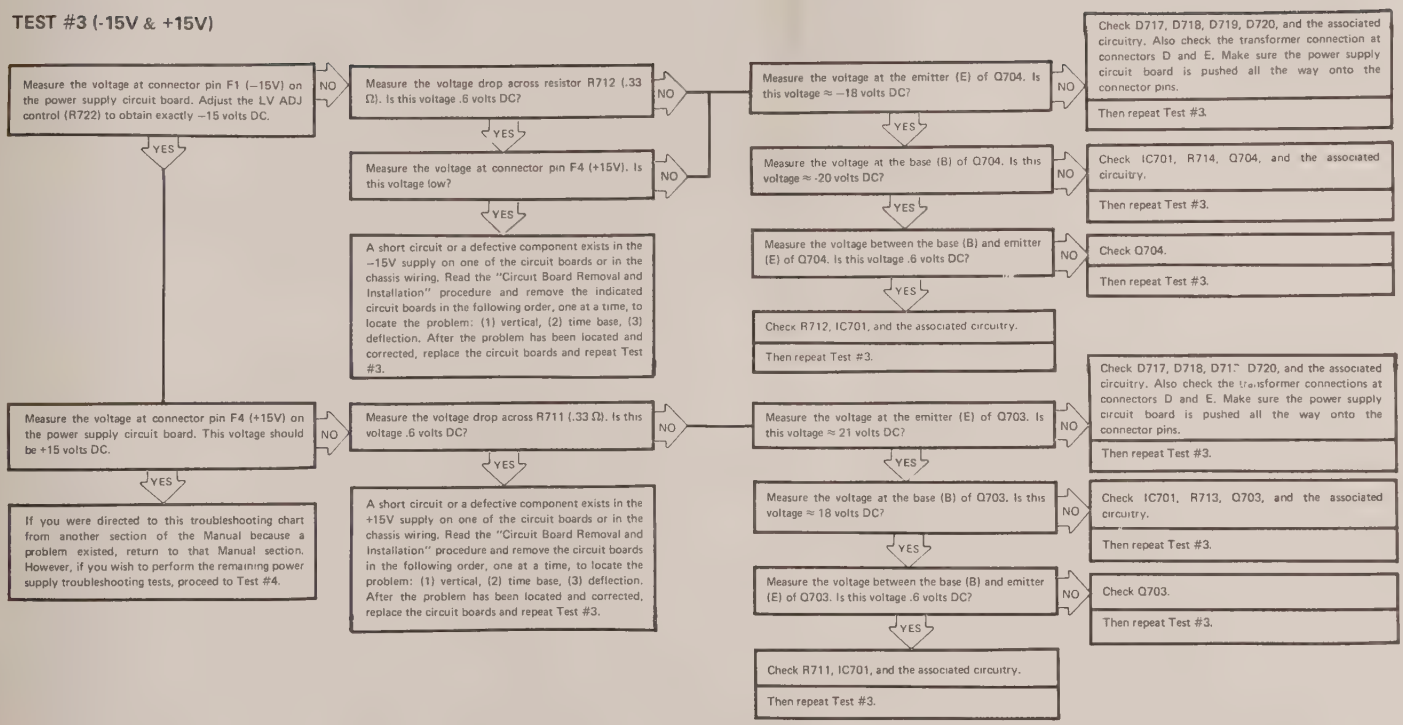
TEST #1 (+ 5V)


Measure the voltage at connector pin G2 (+5V) on the power supply circuit board. This voltage should be +5 volts DC.
NO
YES
If you were directed to this troubleshooting chart from another section of the Manual because a problem existed, return to that Manual section. However, if you wish to perform the remaining power supply troubleshooting tests, proceed to Test #2.
Measure the voltage drop across resistor R716 (1 Ω). Is this voltage .6 volts DC or more ?
NO
YES
A short circuit or a defective component exists in the +5V supply on one of the circuit boards or in the chassis wiring. Read the "Circuit Board Removal and Installation" section and remove the circuit boards one at a time in the following order to locate the problem: (1) time base, (2) vertical, (3) deflection. After the problem has been located and corrected, replace the circuit boards and repeat Test #1.
Measure the voltage at the collector (C) of Q706. Is this voltage ≈ 8 volts DC?
NO
YES
Check D721, D722, D723, D724, and the associated circuitry. Also check the transformer connections at connectors D and E.
Then repeat Test #1
Measure the voltage at the base (B) of Q706. Is this voltage +6.2 volts DC?
NO
YES
Check ZD725, R717, Q705, R716, and the associated circuitry
Then repeat Test #1
Measure the voltage between the base (B) and emitter (E) of Q706. Is this voltage .6 volts DC?
NO
YES
Check Q706
Then repeat Test #1.
Check R716 and the associated circuitry
Then repeat Test #1

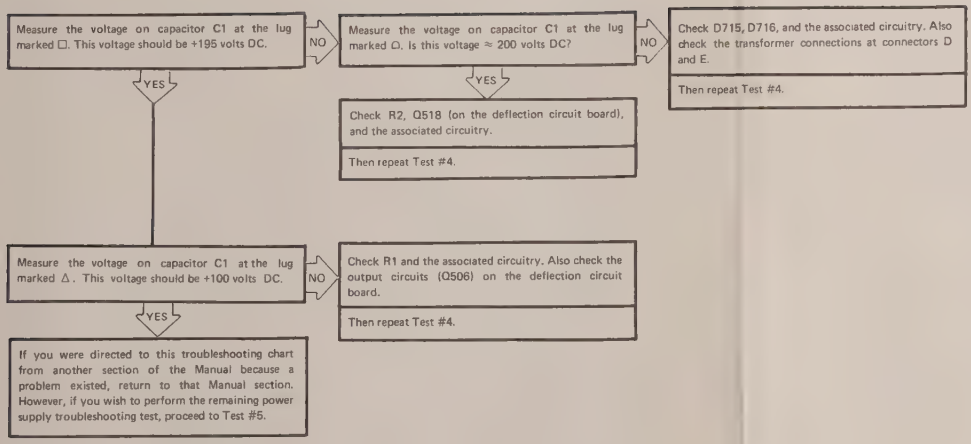
TEST #2 (-5V)


Measure the voltage at connector pin G1 (-5V) on the power supply circuit board. This voltage should be -5 volts DC.
NO
Measure the voltage drop across resistor R718 (4.7 Ω). Is this voltage .6 volts DC or more?
NO
Measure the voltage at the collector (C) of Q708. Is this voltage ≈ -8 volts DC?
NO
Check D721, D722, D723, D724, and the associated circuitry. Also check the transformer connections at connectors D and E.
Then repeat Test #2.
YES
A short circuit or a defective component exists in the -5V supply on the time base circuit board or in the chassis wiring. Read the "Circuit Board Removal and Installation" section and remove the circuit board to locate the problem. After the problem has been located and corrected, replace the circuit boards and repeat Test #2.
YES
Measure the voltage at the base (B) of Q708. Is this voltage -6.2 volts DC?
NO
Check ZD726, R719, Q707, R718, and the associated circuitry.
Then repeat Test #2.
YES
Measure the voltage between the base (B) and emitter (E) of Q708. Is this voltage .6 volts DC?
NO
Check Q708
Then repeat Test #2.
YES
Check R718 and the associated circuitry.
Then repeat Test #2.
YES
If you were directed to this troubleshooting chart from another section of the Manual because a problem existed, return to that Manual section. However, if you wish to perform the remaining power supply troubleshooting tests, proceed to Test #3.

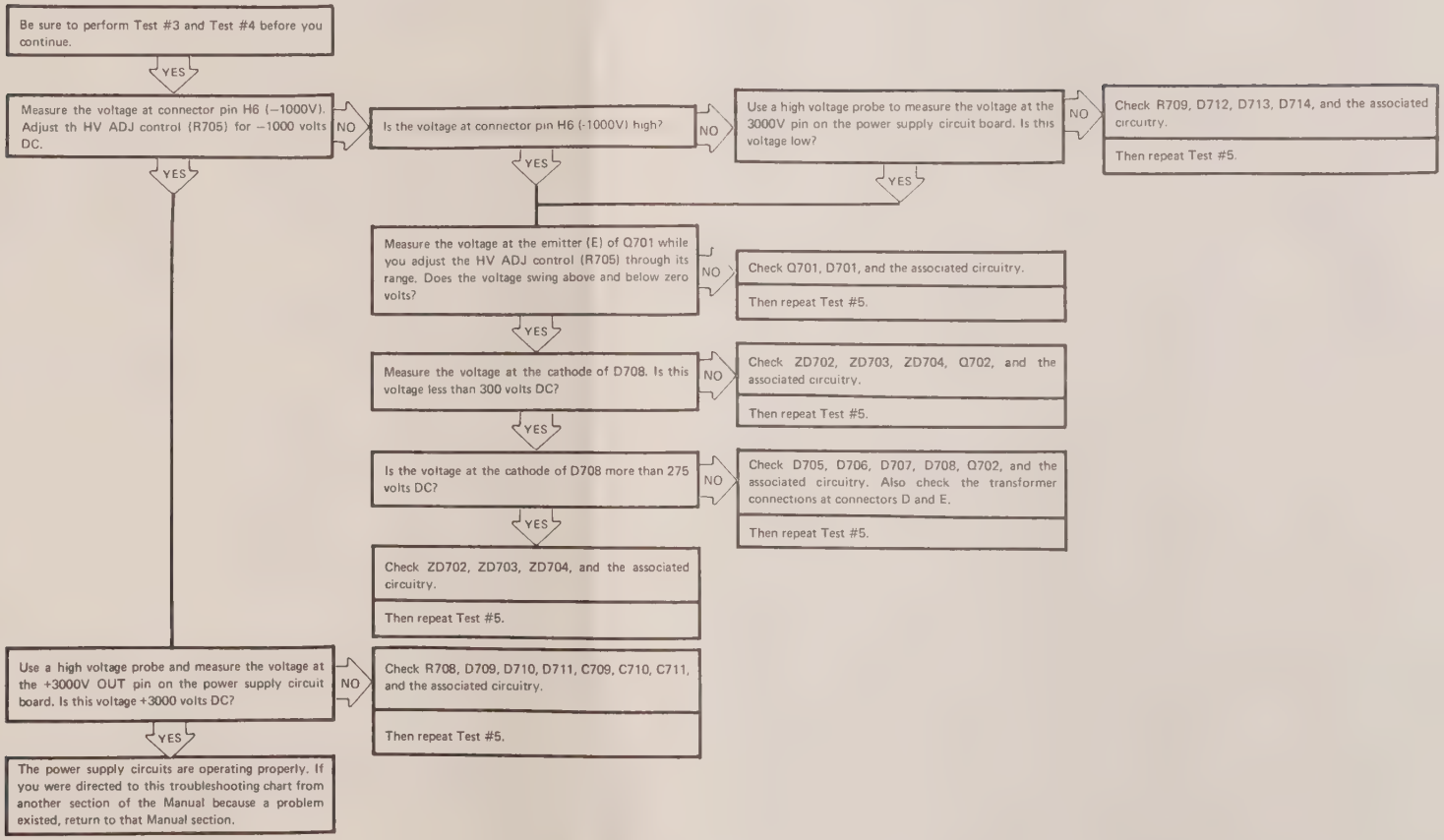
TEST #3 (-15V & +15V)


Measure the voltage at connector pin F1 (–15V) on the power supply circuit board. Adjust the LV ADJ control (R722) to obtain exactly –15 volts DC.
NO
YES
Measure the voltage drop across resistor R712 (.33 Ω). Is this voltage .6 volts DC?
NO
YES
Measure the voltage at connector pin F4 (+15V). Is this voltage low?
NO
YES
A short circuit or a defective component exists in the –15V supply on one of the circuit boards or in the chassis wiring. Read the "Circuit Board Removal and Installation" procedure and remove the indicated circuit boards in the following order, one at a time, to locate the problem: (1) vertical, (2) time base, (3) deflection. After the problem has been located and corrected, replace the circuit boards and repeat Test #3.
Measure the voltage at the emitter (E) of Q704. Is this voltage ≈ –18 volts DC?
NO
YES
Check D717, D718, D719, D720, and the associated circuitry. Also check the transformer connection at connectors D and E. Make sure the power supply circuit board is pushed all the way onto the connector pins.
Then repeat Test #3.
Measure the voltage at the base (B) of Q704. Is this voltage ≈ -20 volts DC?
NO
YES
Check IC701, R714, Q704, and the associated circuitry.
Then repeat Test #3.
Measure the voltage between the base (B) and emitter (E) of Q704. Is this voltage .6 volts DC?
NO
YES
Check Q704.
Then repeat Test #3.
Check R712, IC701, and the associated circuitry.
Then repeat Test #3.
Measure the voltage at connector pin F4 (+15V) on the power supply circuit board. This voltage should be +15 volts DC.
NO
YES
If you were directed to this troubleshooting chart from another section of the Manual because a problem existed, return to that Manual section. However, if you wish to perform the remaining power supply troubleshooting tests, proceed to Test #4.
Measure the voltage drop across R711 (.33 Ω). Is this voltage .6 volts DC?
NO
YES
A short circuit or a defective component exists in the +15V supply on one of the circuit boards or in the chassis wiring. Read the "Circuit Board Removal and Installation" procedure and remove the circuit boards in the following order, one at a time, to locate the problem: (1) vertical, (2) time base, (3) deflection. After the problem has been located and corrected, replace the circuit boards and repeat Test #3.
Measure the voltage at the emitter (E) of Q703. Is this voltage ≈ 21 volts DC?
NO
YES
Check D717, D718, D719, D720, and the associated circuitry. Also check the transformer connections at connectors D and E. Make sure the power supply circuit board is pushed all the way onto the connector pins.
Then repeat Test #3.
Measure the voltage at the base (B) of Q703. Is this voltage ≈ 18 volts DC?
NO
YES
Check IC701, R713, Q703, and the associated circuitry.
Then repeat Test #3.
Measure the voltage between the base (B) and emitter (E) of Q703. Is this voltage .6 volts DC?
NO
YES
Check Q703.
Then repeat Test #3.
Check R711, IC701, and the associated circuitry.
Then repeat Test #3.

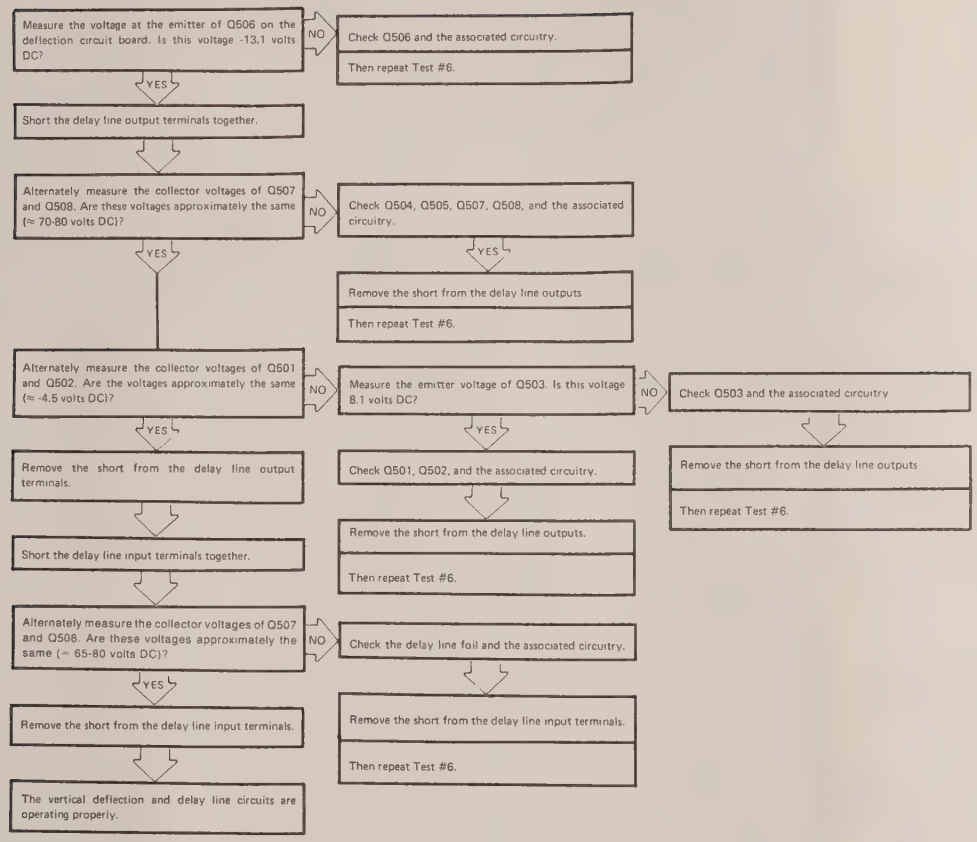
TEST #4 (+195V/+90V)


Measure the voltage on capacitor C1 at the lug marked □. This voltage should be +195 volts DC.
NO
Measure the voltage on capacitor C1 at the lug marked □. Is this voltage ≈ 200 volts DC?
NO
Check D715, D716, and the associated circuitry. Also check the transformer connections at connectors D and E.
Then repeat Test #4.
YES
Check R2, Q518 (on the deflection circuit board), and the associated circuitry.
Then repeat Test #4.
YES
Measure the voltage on capacitor C1 at the lug marked △. This voltage should be +100 volts DC.
NO
Check R1 and the associated circuitry. Also check the output circuits (Q506) on the deflection circuit board.
Then repeat Test #4.
YES
If you were directed to this troubleshooting chart from another section of the Manual because a problem existed, return to that Manual section. However, if you wish to perform the remaining power supply troubleshooting test, proceed to Test #5.

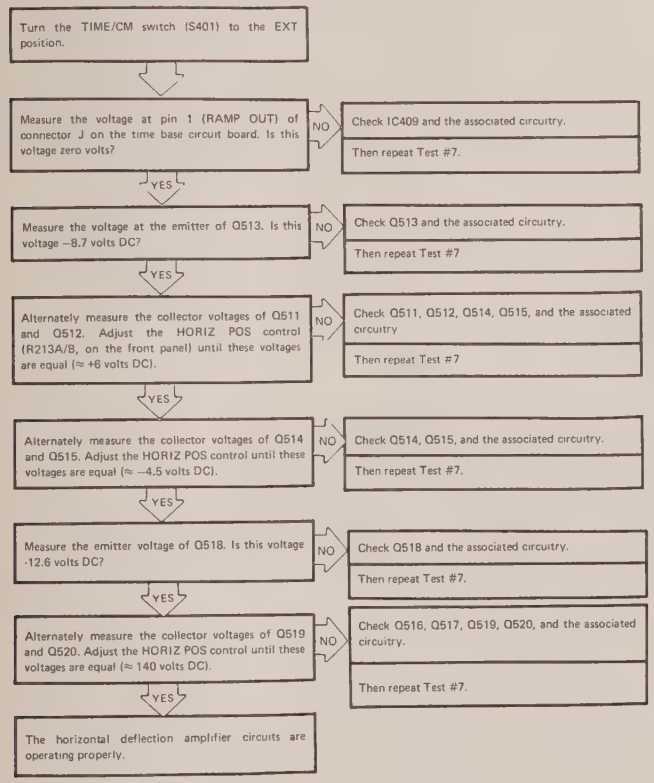
TEST #5 (-1000V/+3000V)


Be sure to perform Test #3 and Test #4 before you continue.
YES
Measure the voltage at connector pin H6 (−1000V). Adjust th HV ADJ control (R705) for −1000 volts DC.
NO
Is the voltage at connector pin H6 (-1000V) high?
NO
Use a high voltage probe to measure the voltage at the 3000V pin on the power supply circuit board. Is this voltage low?
NO
Check R709, D712, D713, D714, and the associated circuitry.
Then repeat Test #5.
YES
YES
Measure the voltage at the emitter (E) of Q701 while you adjust the HV ADJ control (R705) through its range. Does the voltage swing above and below zero volts?
NO
Check Q701, D701, and the associated circuitry.
Then repeat Test #5.
YES
Measure the voltage at the cathode of D708. Is this voltage less than 300 volts DC?
NO
Check ZD702, ZD703, ZD704, Q702, and the associated circuitry.
Then repeat Test #5.
YES
Is the voltage at the cathode of D708 more than 275 volts DC?
NO
Check D705, D706, D707, D708, Q702, and the associated circuitry. Also check the transformer connections at connectors D and E.
Then repeat Test #5.
YES
Check ZD702, ZD703, ZD704, and the associated circuitry.
Then repeat Test #5.
Use a high voltage probe and measure the voltage at the +3000V OUT pin on the power supply circuit board. Is this voltage +3000 volts DC?
NO
Check R708, D709, D710, D711, C709, C710, C711, and the associated circuitry.
Then repeat Test #5.
YES
The power supply circuits are operating properly. If you were directed to this troubleshooting chart from another section of the Manual because a problem existed, return to that Manual section.

TEST #6 (Vertical Deflection Amplifier)


Measure the voltage at the emitter of Q506 on the deflection circuit board. Is this voltage -13.1 volts DC?
NO
Check Q506 and the associated circuitry.
Then repeat Test #6.
YES
Short the delay line output terminals together.
Alternately measure the collector voltages of Q507 and Q508. Are these voltages approximately the same (≈ 70-80 volts DC)?
NO
Check Q504, Q505, Q507, Q508, and the associated circuitry.
YES
Remove the short from the delay line outputs
Then repeat Test #6.
YES
Alternately measure the collector voltages of Q501 and Q502. Are the voltages approximately the same (≈ -4.5 volts DC)?
NO
Measure the emitter voltage of Q503. Is this voltage 8.1 volts DC?
NO
Check Q503 and the associated circuitry
YES
Remove the short from the delay line outputs
Then repeat Test #6.
YES
Check Q501, Q502, and the associated circuitry.
Remove the short from the delay line output terminals.
Remove the short from the delay line outputs.
Then repeat Test #6.
Short the delay line input terminals together.
Alternately measure the collector voltages of Q507 and Q508. Are these voltages approximately the same (≈ 65-80 volts DC)?
NO
Check the delay line foil and the associated circuitry.
YES
Remove the short from the delay line input terminals.
Remove the short from the delay line input terminals.
Then repeat Test #6.
The vertical deflection and delay line circuits are operating properly.

TEST #7 (Horizontal Deflection Amplifier)


Turn the TIME/CM switch (S401) to the EXT position.
Measure the voltage at pin 1 (RAMP OUT) of connector J on the time base circuit board. Is this voltage zero volts?
NO
Check IC409 and the associated circuitry.
Then repeat Test #7.
YES
Measure the voltage at the emitter of Q513. Is this voltage −8.7 volts DC?
NO
Check Q513 and the associated circuitry.
Then repeat Test #7
YES
Alternately measure the collector voltages of Q511 and Q512. Adjust the HORIZ POS control (R213A/B, on the front panel) until these voltages are equal (≈ +6 volts DC).
NO
Check Q511, Q512, Q514, Q515, and the associated circuitry
Then repeat Test #7
YES
Alternately measure the collector voltages of Q514 and Q515. Adjust the HORIZ POS control until these voltages are equal (≈ −4.5 volts DC).
NO
Check Q514, Q515, and the associated circuitry.
Then repeat Test #7.
YES
Measure the emitter voltage of Q518. Is this voltage -12.6 volts DC?
NO
Check Q518 and the associated circuitry.
Then repeat Test #7.
YES
Alternately measure the collector voltages of Q519 and Q520. Adjust the HORIZ POS control until these voltages are equal (≈ 140 volts DC).
NO
Check Q516, Q517, Q519, Q520, and the associated circuitry.
Then repeat Test #7.
YES
The horizontal deflection amplifier circuits are operating properly.

TEST #8 (Y1 Vertical Preamplifier)

Measure the voltage at the emitter of Q116-1. Is this voltage 11.6 volts DC?
- NO → Check Q116-1 and the associated circuitry. Then repeat Test #8.
- YES → Short the collectors of Q110-1 and Q111-1 together.

Alternately measure the voltage at pin 4 (V OUT) and pin 6 (V. OUT) of connector C. Are these voltages approximately the same (≈ -2.3 volts)?
- NO → Remove the short from between the collectors of Q110-1 and Q111-1. Short the base of Q112 and Q113 together.
- YES → Remove the short from between the collectors of Q110-1 and Q111-1.

Alternately measure the voltage at pin 4 (V OUT) and pin 6 (V OUT) of connector C. Are these voltages approximately the same (≈ -2.3 volts DC)?
- NO → Check Q112, Q113, and the associated circuitry. Remove the short from between the bases of Q112 and Q113. Then repeat Test #8.
- YES → Remove the short from between the bases of Q112 and Q113.

Short the emitters of Q108-1 and Q109-1 together.

Measure the voltage at the cathode of D107-1. Is this voltage ≈ 3.5 volts DC?
- NO → Check IC101, Q121, Q122 and the associated circuitry.
- YES → Check D107-1, D108-1, D109-1, D110-1, and the associated circuitry. Then repeat Test #8.

Measure the voltage at pin 6 (Y1 TR OUT) of connector B. Adjust the Y1 DC TRIG ADJ control (R176-1) for zero volts.
- NO → Check Q117-1, Q118-1, Q119-1, Q120-1, and the associated circuitry. Remove the short from between the emitters of Q108-1 and Q109-1. Then repeat Test #8.
- YES → Alternately measure the voltage at pin 4 (V OUT) and pin 6 (V. OUT) of connector C. Are these voltages approximately the same (≈ -2.3 volts DC)?
  - NO → Check Q110-1, Q111-1, and the associated circuitry. Remove the short from between the emitters of Q108-1 and Q109-1. Then repeat Test #8.
  - YES → Remove the short from between the emitters of Q108-1 and Q109-1.

TEST #8 Cont'd.

Measure the voltage at the emitter of Q115-1. Is this voltage –11.7 volts DC?
- NO → Check Q115-1 and the associated circuitry. Then repeat Test #8
- YES → Short the emitters of Q104-1 and Q105-1 together

Turn the Y1 POSITION control (R148-1) and the Y1 COARSE BAL control (R150-1) to the center of rotation.

Set your voltmeter to the 1.5 VDC range. Connect the negative voltmeter lead to pin 6 (V OUT) of connector C. Connect the positive lead to pin 4 (V OUT) of connector C. CAUTION: Be sure the negative voltmeter lead is not connected to AC ground within the voltmeter. Use an isolation plug (3-prong adapter plug) if necessary

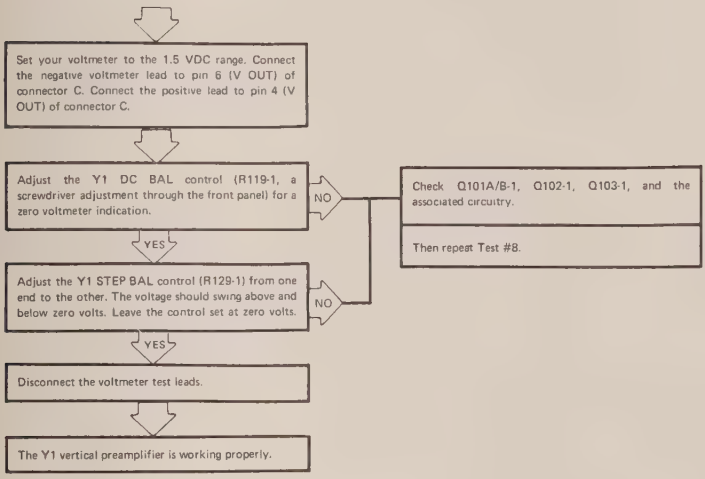
Adjust the Y1 COARSE BAL control (R150-1) for a zero voltmeter indication. NOTE: This and the following adjustments are quite sensitive.
- NO → Remove the short from between the emitters of Q104-1 and Q105-1. Short the bases of Q108-1 and Q109-1 together. Is the voltage ≈ 0 volts?
  - NO → Check Q108-1, Q109-1, and the associated circuitry. Remove the short from between the bases of Q108-1 and Q109-1. Then repeat Test #8
  - YES → Check Q106-1, Q107-1, and the associated circuitry. Remove the short from between the bases of Q108-1 and Q109-1. Then repeat Test #8
- YES → Remove the short from between the emitters of Q104-1 and Q105-1.

Disconnect the voltmeter leads from pins 4 and 6 of connector C.

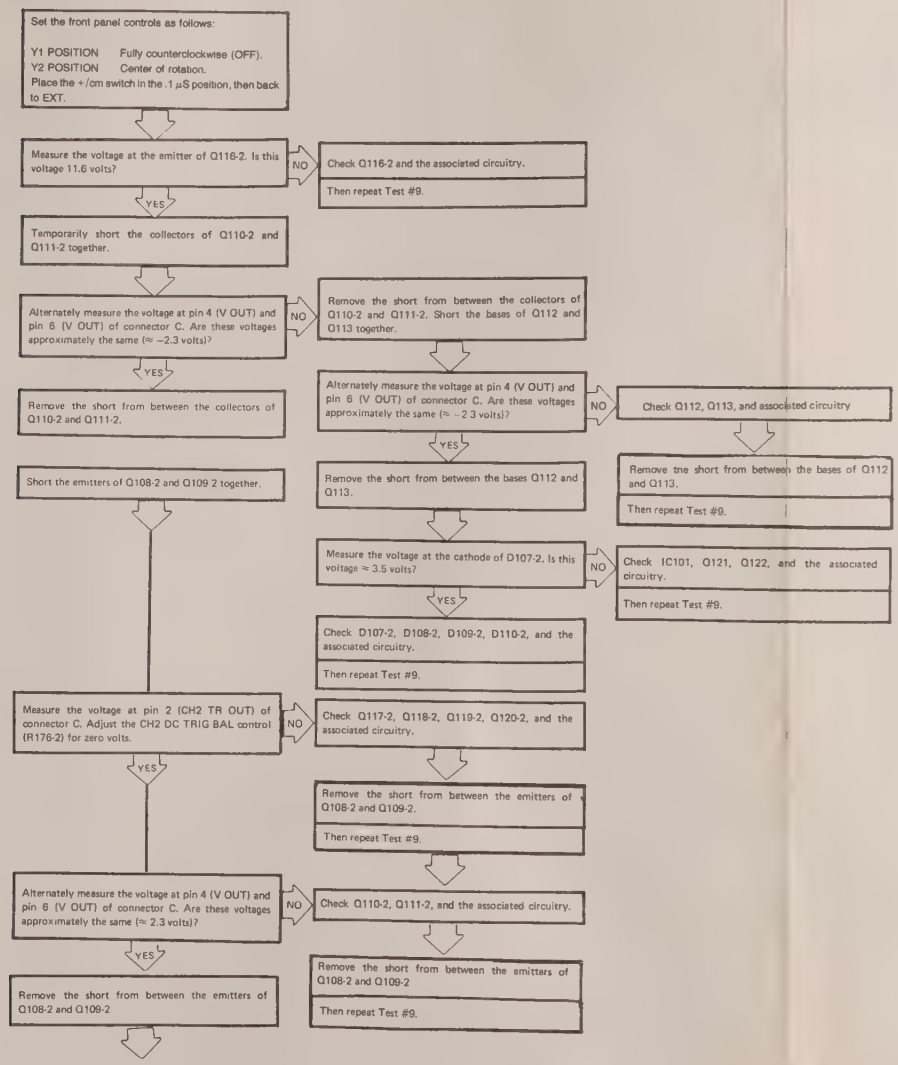
Connect the negative voltmeter test lead to the chassis.

Measure the voltage at the emitter of Q114-1. Is this voltage 11.7 volts DC?
- NO → Check Q114-1 and the associated circuitry. Then repeat Test #8.
- YES → Turn the Y1 VOLTS/CM switch (S102-1) to the .2 V position. Turn the Y1 STEP BAL control (R129-1) to the center of rotation.

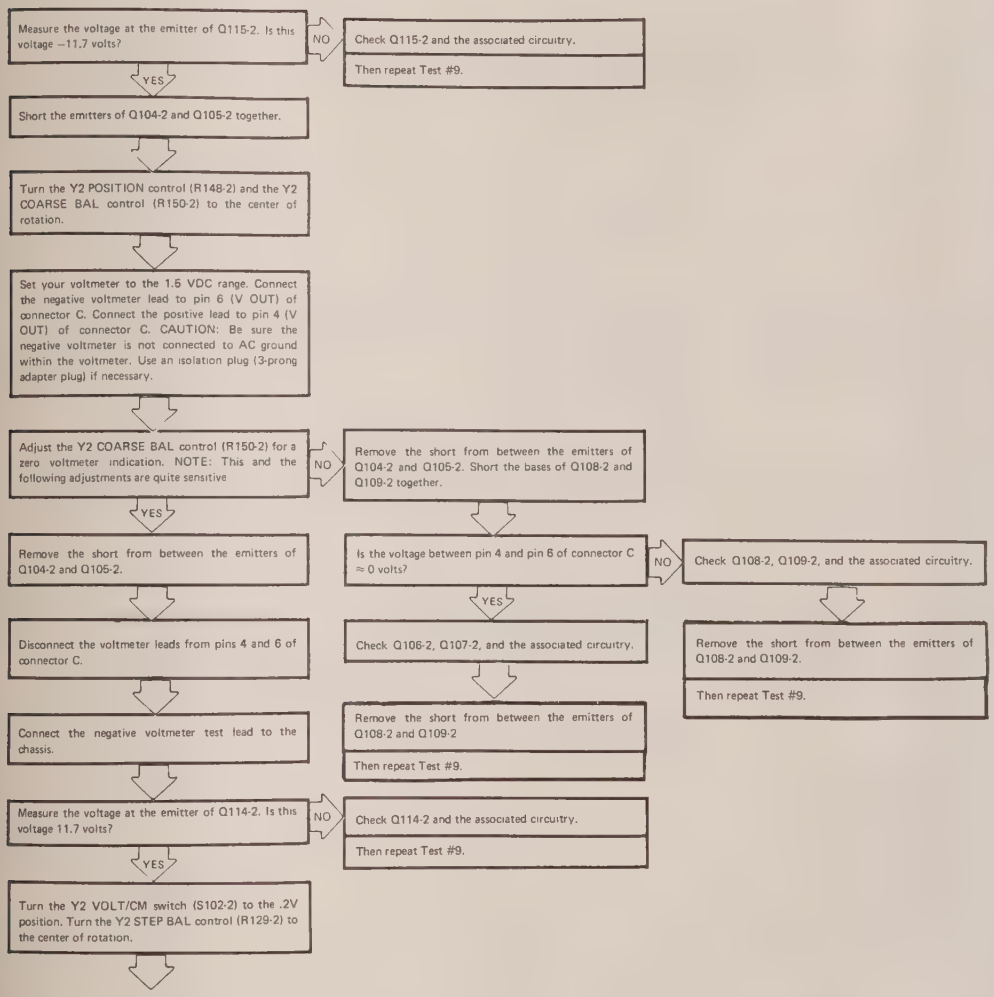
TEST #8 Cont'd.


Set your voltmeter to the 1.5 VDC range. Connect the negative voltmeter lead to pin 6 (V OUT) of connector C. Connect the positive lead to pin 4 (V OUT) of connector C.
Adjust the Y1 DC BAL control (R119-1, a screwdriver adjustment through the front panel) for a zero voltmeter indication.
NO
Check Q101A/B-1, Q102-1, Q103-1, and the associated circuitry.
Then repeat Test #8.
YES
Adjust the Y1 STEP BAL control (R129-1) from one end to the other. The voltage should swing above and below zero volts. Leave the control set at zero volts.
NO
YES
Disconnect the voltmeter test leads.
The Y1 vertical preamplifier is working properly.

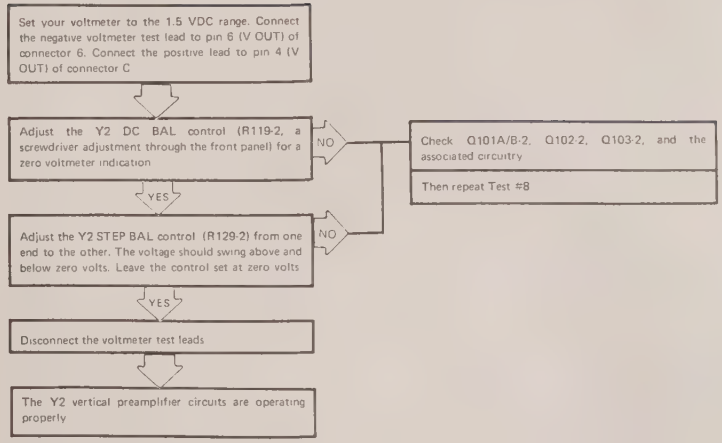
TEST #9 (Y2 Vertical Preamplifier)


Set the front panel controls as follows:
Y1 POSITION Fully counterclockwise (OFF).
Y2 POSITION Center of rotation.
Place the +/cm switch in the .1 μS position, then back to EXT.
Measure the voltage at the emitter of Q116-2. Is this voltage 11.6 volts?
NO
Check Q116-2 and the associated circuitry.
Then repeat Test #9.
YES
Temporarily short the collectors of Q110-2 and Q111-2 together.
Alternately measure the voltage at pin 4 (V OUT) and pin 6 (V OUT) of connector C. Are these voltages approximately the same (≈ −2.3 volts)?
NO
Remove the short from between the collectors of Q110-2 and Q111-2. Short the bases of Q112 and Q113 together.
YES
Remove the short from between the collectors of Q110-2 and Q111-2.
Alternately measure the voltage at pin 4 (V OUT) and pin 6 (V OUT) of connector C. Are these voltages approximately the same (≈ −2.3 volts)?
NO
Check Q112, Q113, and associated circuitry
Remove the short from between the bases of Q112 and Q113.
Then repeat Test #9.
YES
Short the emitters of Q108-2 and Q109-2 together.
Remove the short from between the bases of Q112 and Q113.
Measure the voltage at the cathode of D107-2. Is this voltage ≈ 3.5 volts?
NO
Check IC101, Q121, Q122, and the associated circuitry.
Then repeat Test #9.
YES
Check D107-2, D108-2, D109-2, D110-2, and the associated circuitry.
Then repeat Test #9.
Measure the voltage at pin 2 (CH2 TR OUT) of connector C. Adjust the CH2 DC TRIG BAL control (R176-2) for zero volts.
NO
Check Q117-2, Q118-2, Q119-2, Q120-2, and the associated circuitry.
YES
Remove the short from between the emitters of Q108-2 and Q109-2.
Then repeat Test #9.
Alternately measure the voltage at pin 4 (V OUT) and pin 6 (V OUT) of connector C. Are these voltages approximately the same (≈ 2.3 volts)?
NO
Check Q110-2, Q111-2, and the associated circuitry.
YES
Remove the short from between the emitters of Q108-2 and Q109-2
Remove the short from between the emitters of Q108-2 and Q109-2
Then repeat Test #9.

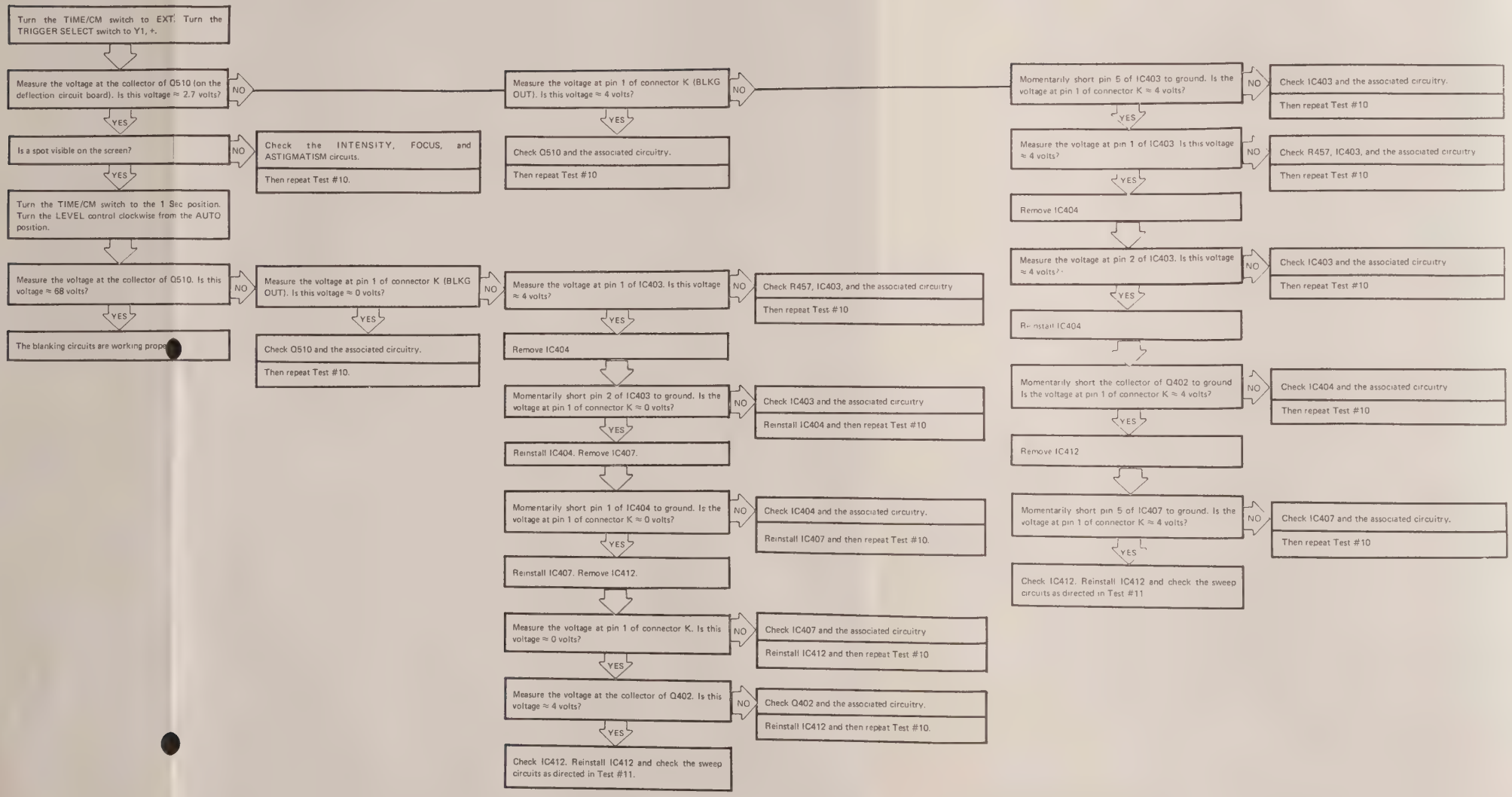
TEST #9 cont'd.


Measure the voltage at the emitter of Q115-2. Is this voltage −11.7 volts?
NO
Check Q115-2 and the associated circuitry.
Then repeat Test #9.
YES
Short the emitters of Q104-2 and Q105-2 together.
Turn the Y2 POSITION control (R148-2) and the Y2 COARSE BAL control (R150-2) to the center of rotation.
Set your voltmeter to the 1.5 VDC range. Connect the negative voltmeter lead to pin 6 (V OUT) of connector C. Connect the positive lead to pin 4 (V OUT) of connector C. CAUTION: Be sure the negative voltmeter is not connected to AC ground within the voltmeter. Use an isolation plug (3-prong adapter plug) if necessary.
Adjust the Y2 COARSE BAL control (R150-2) for a zero voltmeter indication. NOTE: This and the following adjustments are quite sensitive
NO
Remove the short from between the emitters of Q104-2 and Q105-2. Short the bases of Q108-2 and Q109-2 together.
YES
Remove the short from between the emitters of Q104-2 and Q105-2.
Is the voltage between pin 4 and pin 6 of connector C ≈ 0 volts?
NO
Check Q108-2, Q109-2, and the associated circuitry.
Remove the short from between the emitters of Q108-2 and Q109-2.
Then repeat Test #9.
YES
Check Q106-2, Q107-2, and the associated circuitry.
Disconnect the voltmeter leads from pins 4 and 6 of connector C.
Remove the short from between the emitters of Q108-2 and Q109-2
Then repeat Test #9.
Connect the negative voltmeter test lead to the chassis.
Measure the voltage at the emitter of Q114-2. Is this voltage 11.7 volts?
NO
Check Q114-2 and the associated circuitry.
Then repeat Test #9.
YES
Turn the Y2 VOLT/CM switch (S102-2) to the .2V position. Turn the Y2 STEP BAL control (R129-2) to the center of rotation.

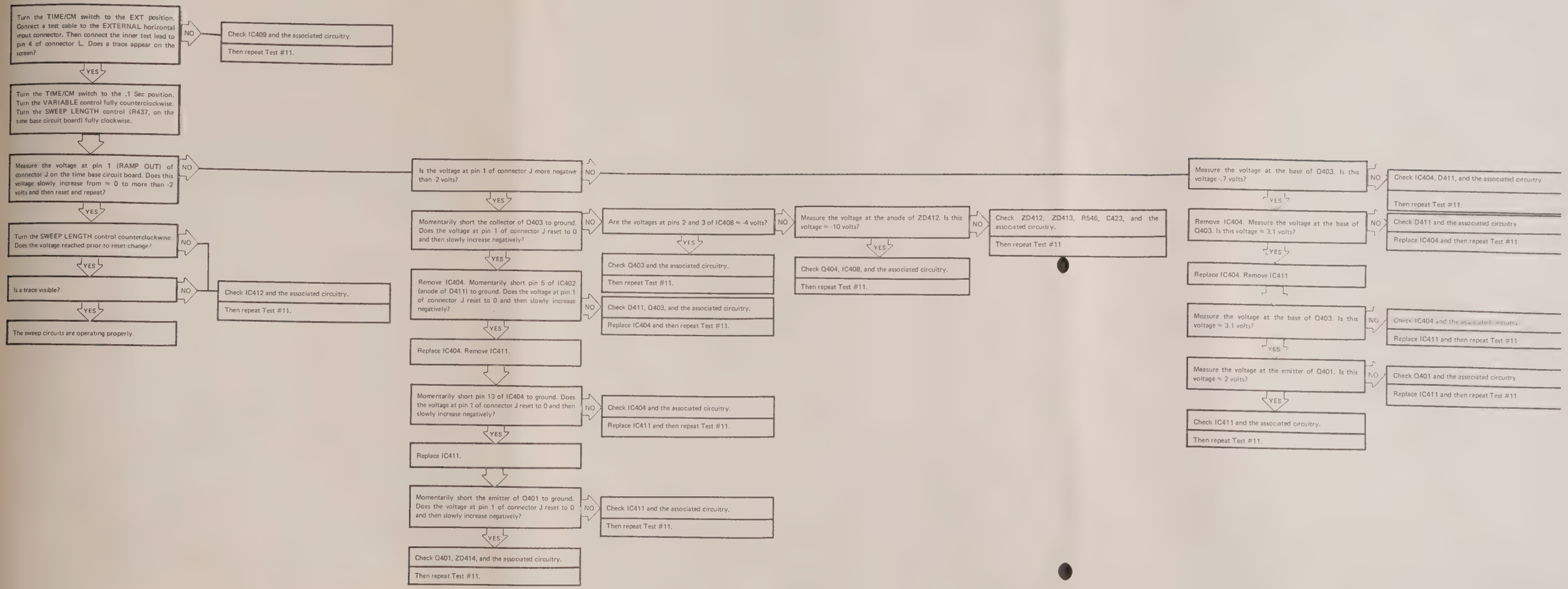
TEST #9 Cont'd.


Set your voltmeter to the 1.5 VDC range. Connect the negative voltmeter test lead to pin 6 (V OUT) of connector 6. Connect the positive lead to pin 4 (V OUT) of connector C
Adjust the Y2 DC BAL control (R119-2, a screwdriver adjustment through the front panel) for a zero voltmeter indication
NO
Check Q101A/B-2, Q102-2, Q103-2, and the associated circuitry
Then repeat Test #8
YES
Adjust the Y2 STEP BAL control (R129-2) from one end to the other. The voltage should swing above and below zero volts. Leave the control set at zero volts
NO
YES
Disconnect the voltmeter test leads
The Y2 vertical preamplifier circuits are operating properly

TEST #10 (Blanking Circuits)


Turn the TIME/CM switch to EXT. Turn the TRIGGER SELECT switch to Y1, +.
Measure the voltage at the collector of Q510 (on the deflection circuit board). Is this voltage ≈ 2.7 volts?
NO
YES
Is a spot visible on the screen?
NO
Check the INTENSITY, FOCUS, and ASTIGMATISM circuits.
Then repeat Test #10.
YES
Turn the TIME/CM switch to the 1 Sec position. Turn the LEVEL control clockwise from the AUTO position.
Measure the voltage at the collector of Q510. Is this voltage ≈ 68 volts?
NO
YES
The blanking circuits are working properly.
Measure the voltage at pin 1 of connector K (BLKG OUT). Is this voltage ≈ 0 volts?
NO
YES
Check Q510 and the associated circuitry.
Then repeat Test #10.
Measure the voltage at pin 1 of connector K (BLKG OUT). Is this voltage ≈ 4 volts?
NO
YES
Check Q510 and the associated circuitry.
Then repeat Test #10
Measure the voltage at pin 1 of IC403. Is this voltage ≈ 4 volts?
NO
YES
Check R457, IC403, and the associated circuitry
Then repeat Test #10
Remove IC404
Momentarily short pin 2 of IC403 to ground. Is the voltage at pin 1 of connector K ≈ 0 volts?
NO
YES
Check IC403 and the associated circuitry
Reinstall IC404 and then repeat Test #10
Reinstall IC404. Remove IC407.
Momentarily short pin 1 of IC404 to ground. Is the voltage at pin 1 of connector K ≈ 0 volts?
NO
YES
Check IC404 and the associated circuitry.
Reinstall IC407 and then repeat Test #10.
Reinstall IC407. Remove IC412.
Measure the voltage at pin 1 of connector K. Is this voltage ≈ 0 volts?
NO
YES
Check IC407 and the associated circuitry
Reinstall IC412 and then repeat Test #10
Measure the voltage at the collector of Q402. Is this voltage ≈ 4 volts?
NO
YES
Check Q402 and the associated circuitry.
Reinstall IC412 and then repeat Test #10.
Check IC412. Reinstall IC412 and check the sweep circuits as directed in Test #11.
Momentarily short pin 5 of IC403 to ground. Is the voltage at pin 1 of connector K ≈ 4 volts?
NO
YES
Check IC403 and the associated circuitry.
Then repeat Test #10
Measure the voltage at pin 1 of IC403. Is this voltage ≈ 4 volts?
NO
YES
Check R457, IC403, and the associated circuitry
Then repeat Test #10
Remove IC404
Measure the voltage at pin 2 of IC403. Is this voltage ≈ 4 volts?
NO
YES
Check IC403 and the associated circuitry
Then repeat Test #10
Reinstall IC404
Momentarily short the collector of Q402 to ground Is the voltage at pin 1 of connector K ≈ 4 volts?
NO
YES
Check IC404 and the associated circuitry
Then repeat Test #10
Remove IC412
Momentarily short pin 5 of IC407 to ground. Is the voltage at pin 1 of connector K ≈ 4 volts?
NO
YES
Check IC407 and the associated circuitry.
Then repeat Test #10
Check IC412. Reinstall IC412 and check the sweep circuits as directed in Test #11

TEST #11 (Sweep Circuits)


Turn the TIME/CM switch to the EXT position. Connect a test cable to the EXTERNAL horizontal input connector. Then connect the inner test lead to pin 4 of connector L. Does a trace appear on the screen?
NO
Check IC409 and the associated circuitry.
Then repeat Test #11.
YES
Turn the TIME/CM switch to the .1 Sec position. Turn the VARIABLE control fully counterclockwise. Turn the SWEEP LENGTH control (R437, on the time base circuit board) fully clockwise.
Measure the voltage at pin 1 (RAMP OUT) of connector J on the time base circuit board. Does this voltage slowly increase from ≈ 0 to more than -2 volts and then reset and repeat?
NO
YES
Turn the SWEEP LENGTH control counterclockwise. Does the voltage reached prior to reset change?
NO
YES
Is a trace visible?
NO
YES
Check IC412 and the associated circuitry.
Then repeat Test #11.
The sweep circuits are operating properly.
Is the voltage at pin 1 of connector J more negative than -2 volts?
NO
YES
Momentarily short the collector of Q403 to ground. Does the voltage at pin 1 of connector J reset to 0 and then slowly increase negatively?
NO
YES
Remove IC404. Momentarily short pin 5 of IC402 (anode of D411) to ground. Does the voltage at pin 1 of connector J reset to 0 and then slowly increase negatively?
NO
YES
Replace IC404. Remove IC411.
Momentarily short pin 13 of IC404 to ground. Does the voltage at pin 1 of connector J reset to 0 and then slowly increase negatively?
NO
YES
Replace IC411.
Momentarily short the emitter of Q401 to ground. Does the voltage at pin 1 of connector J reset to 0 and then slowly increase negatively?
NO
YES
Check Q401, ZD414, and the associated circuitry.
Then repeat Test #11.
Are the voltages at pins 2 and 3 of IC408 ≈ -4 volts?
NO
YES
Check Q403 and the associated circuitry.
Then repeat Test #11.
Check D411, Q403, and the associated circuitry.
Replace IC404 and then repeat Test #11.
Check IC404 and the associated circuitry.
Replace IC411 and then repeat Test #11.
Check IC411 and the associated circuitry.
Then repeat Test #11.
Measure the voltage at the anode of ZD412. Is this voltage ≈ -10 volts?
NO
YES
Check Q404, IC408, and the associated circuitry.
Then repeat Test #11.
Check ZD412, ZD413, R546, C423, and the associated circuitry.
Then repeat Test #11
Measure the voltage at the base of Q403. Is this voltage -.7 volts?
NO
YES
Remove IC404. Measure the voltage at the base of Q403. Is this voltage ≈ 3.1 volts?
NO
YES
Replace IC404. Remove IC411
Measure the voltage at the base of Q403. Is this voltage ≈ 3.1 volts?
NO
YES
Measure the voltage at the emitter of Q401. Is this voltage ≈ 2 volts?
NO
YES
Check IC411 and the associated circuitry.
Then repeat Test #11.
Check IC404, D411, and the associated circuitry
Then repeat Test #11.
Check D411 and the associated circuitry
Replace IC404 and then repeat Test #11
Check IC404 and the associated circuitry
Replace IC411 and then repeat Test #11
Check Q401 and the associated circuitry
Replace IC411 and then repeat Test #11

TEST #12 (Trigger Circuits)

Turn the TIME/CM switch to X-Y. Adjust the Y1 POSITION, Y2 POSITION, and HORIZ POSITION controls to center the spot on the screen. If a spot is not visible, a problem exists in one of the other circuits.

Connect a test cable to the Y1 INPUT connector. Set the front panel controls as follows:

Y1:

INPUT switch	AC
VOLTS/CM	1V
TRIGGER LEVEL	AUTO
TRIGGER SELECT	Y1, +

Touch the inner lead of the test cable to pin 2 of IC407. Does a line 2-5 cm long appear?
- NO → Check IC401 and the associated circuitry. Then repeat Test #12
- YES ↓

Remove IC410. Touch the inner lead of the test cable to pin 3 of IC407. Does a line 3-5 cm long appear?
- NO → Check IC407 and the associated circuitry. Reinstall IC410 and then repeat Test #12.
- YES ↓

Short pin 2 of IC406 to ground. Touch the inner lead of the test cable to pin 8 of IC406. Does a line 3-6 cm long appear?
- NO → Check IC406 and the associated circuitry. Reinstall IC410 and then repeat Test #12
- YES ↓

Remove the short from pin 2 of IC406. Turn the TRIGGER SELECT switch to LINE, +.

Touch the inner lead of the test cable to pin 10 of IC405. Do two dots 3-6 cm apart appear?
- NO → Check IC405 and the associated circuitry. Reinstall IC410 and then repeat Test #12
- YES ↓

Touch the inner lead of the test cable to pin 11 of IC405. Do two dot 3-6 cm apart appear?
- NO → Check IC405 and the associated circuitry. Reinstall IC410 and then repeat Test #12
- YES ↓

Reinstall IC410

Chart #12 (Cont'd)

Turn the TIME/CM switch to the 1 mS position. Does a trace appear?
- NO → Check IC410 and the associated circuitry. Then repeat Test #12
- YES ↓

Turn the TRIGGER SELECT switch to Y1, +

Turn the TRIGGER LEVEL control to the center of rotation (NORMAL). Does the trace disappear?
- NO → Check IC410 and the associated circuitry. Then repeat Test #12
- YES ↓

Turn the TRIGGER SELECT switch to LINE, +. Does the trace reappear?
- NO → Check IC410 and the associated circuitry. Then repeat Test #12
- YES ↓

The trigger circuits are operating properly

COMPONENT IDENTIFICATION

This section of the Manual contains circuit board "X-Ray Views," "Chassis Photographs," and "Component Charts." The X-Ray Views and chassis photographs show the location of the components. The component charts list the components by component number in numerical order. The charts also give the PART NUMBER and DESCRIPTION of each component.

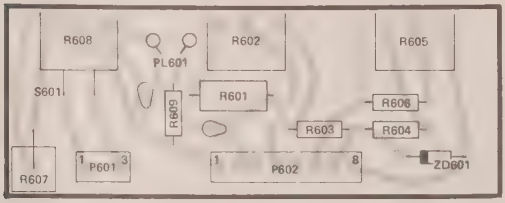
To use the "Component Charts" (when ordering replacement parts, for example):

A. Find the circuit component number (R5, C3, etc.) on the "X-Ray View" or "Chassis Photograph."

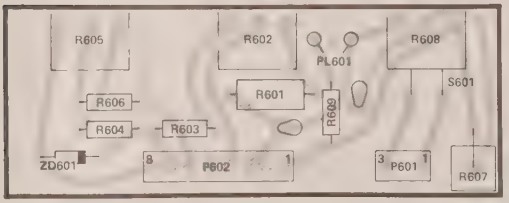
B. Locate this same number in the "Component Number" column of the "Component Chart."

C. Adjacent to the component number, you will find the PART NUMBER and DESCRIPTION.

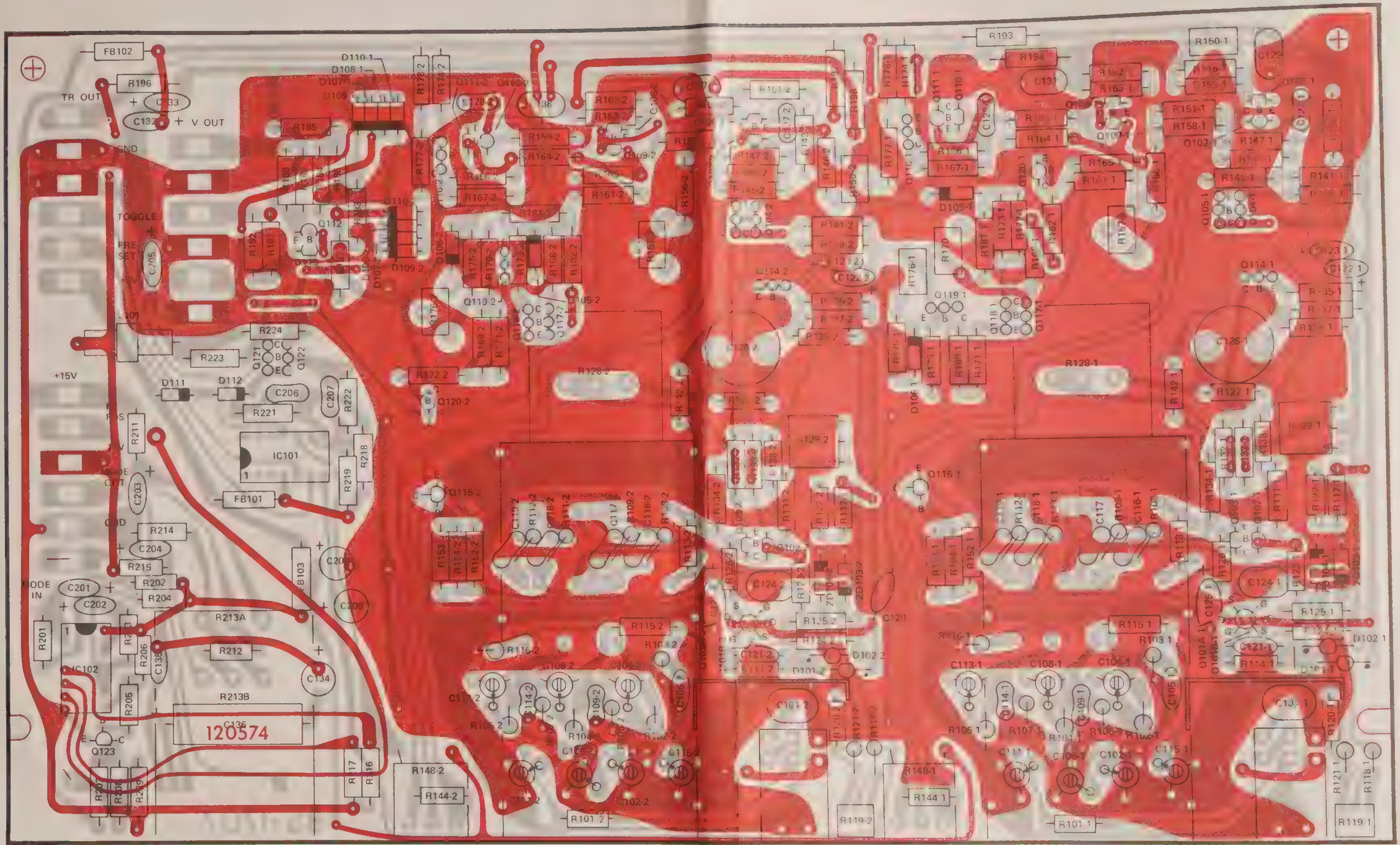
CIRCUIT BOARD X-RAY VIEWS



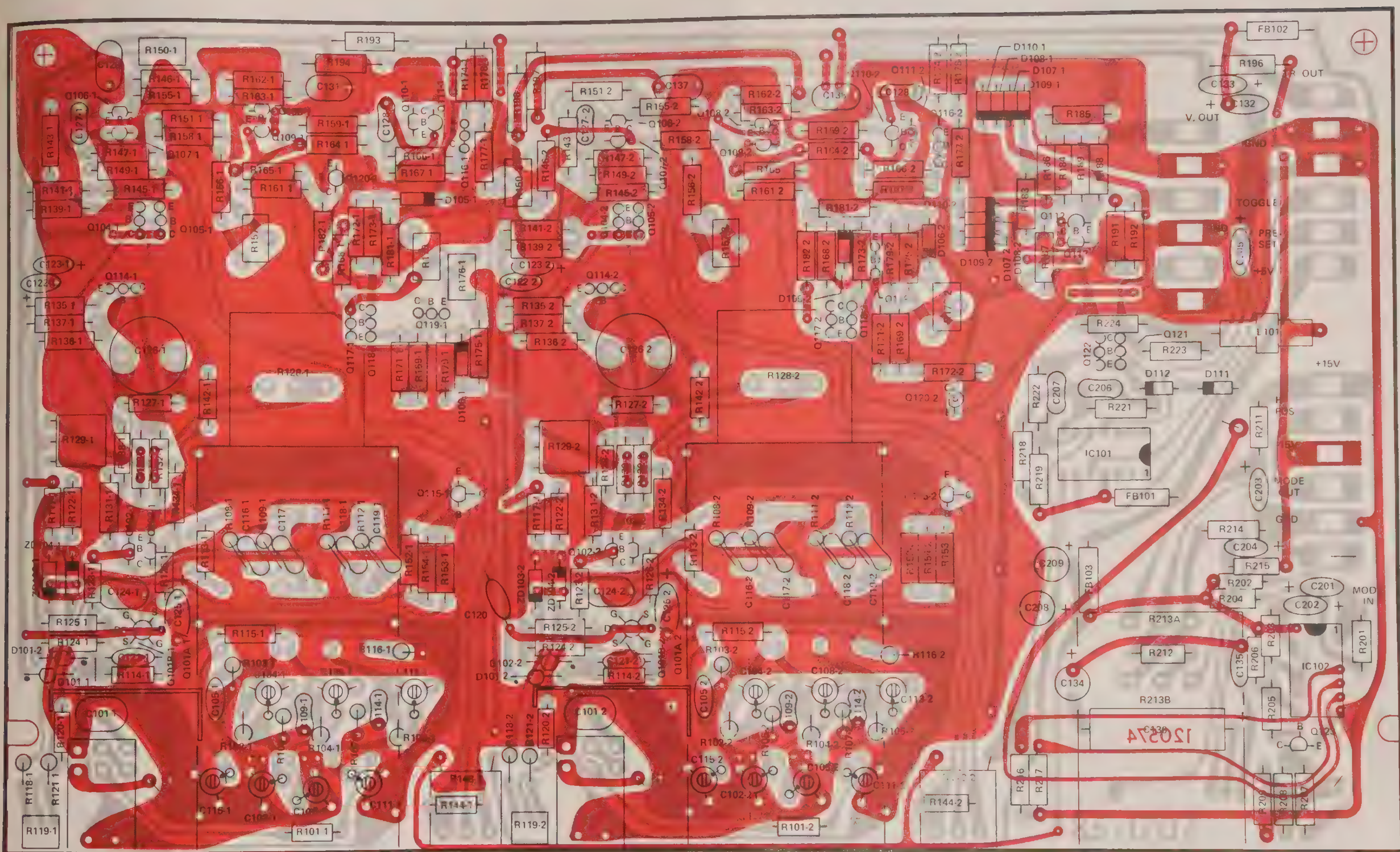
CONTROL BOARD
(Viewed from component side)



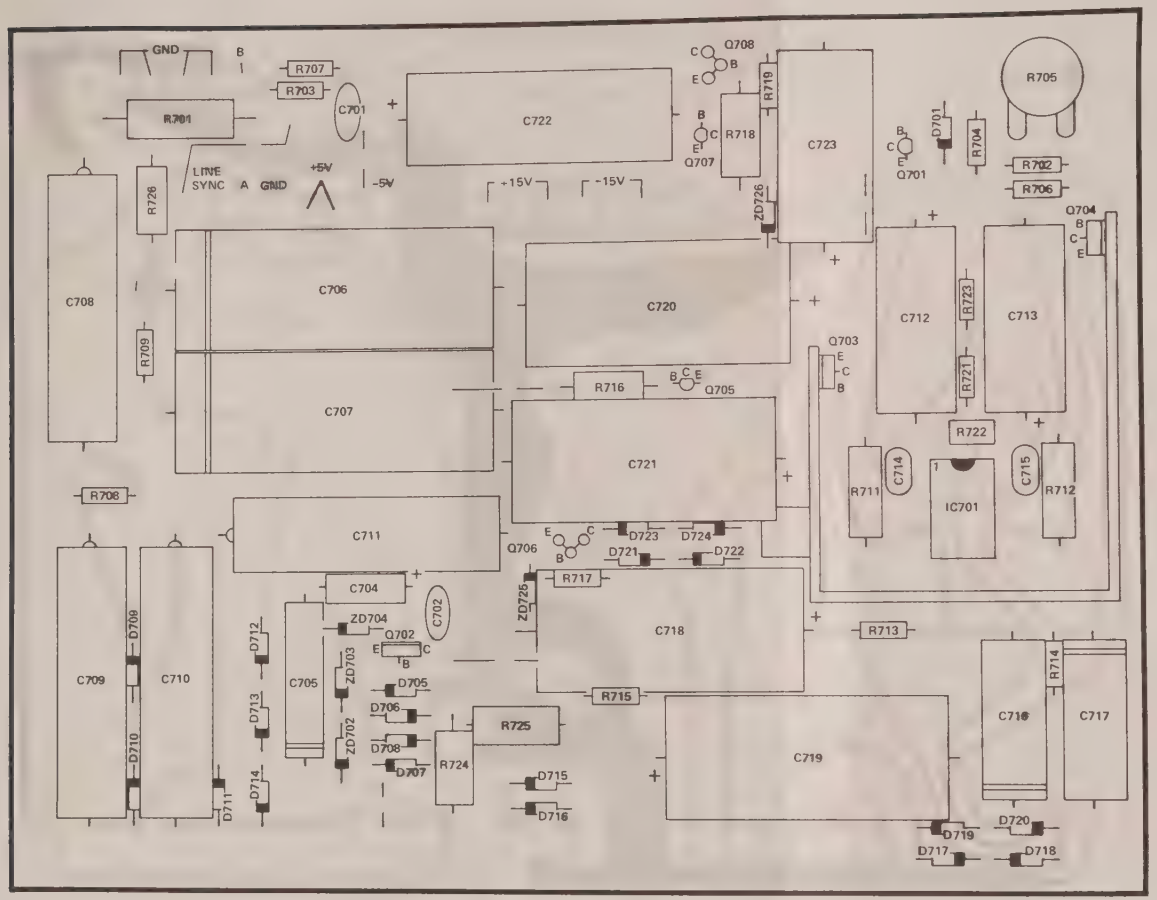
(Viewed from foil side)


FB102
R196
TR OUT
C133
C132
V OUT
GND
TOGGLE
PRESET
C205
R224
R223
Q121
Q122
+15V
D111
D112
C206
R221
C207
R222
R211
IC101
R218
R219
FB101
C203
R214
C204
R215
R202
R204
C201
C202
R201
IC102
R213A
R212
R206
C134
R205
R213B
C136
120574
Q123
R148-2
R144-2
R101 2
R119 2
R148-1
R144 1
R101 1
R119 1
R193
R194
C131
R150-1
C129
R151-1
R158-1
R147 1
R145 1
R141-1
R128-1
R128-2
C126-1
R127 1
R142 1
Q115 1
Q115 2
C124 2
C124 1
R125 1
R115 2
R115 1
R103 1
D102 1
D102 2
D101-2
R121 1
R118 1
R120-1

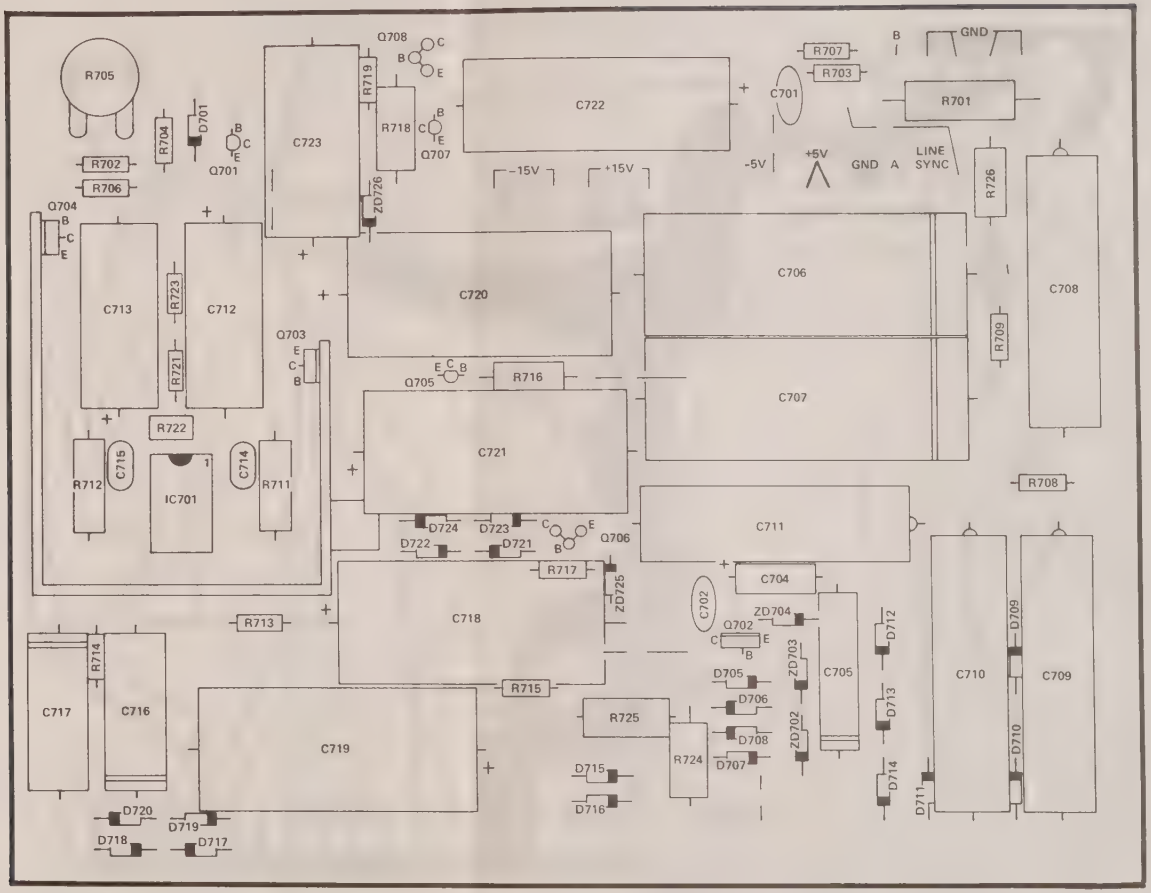
VERTICAL CIRCUIT BOARD
(Shown from component side)


FB102
R196
R OUT
C133
C132
V. OUT
GND
TOGGLE
PRE-SET
+5V
+15V
H POS
15V
MODE OUT
GND
MOD IN
R193
R150-1
R194
R162-1
R163-1
C131
R151 2
C137
R155-2
R162-2
R163-2
Q111 2
D110 1
D108-1
D107 1
D109 1
R185
R191
R192
R224
Q121
R223
Q122
D112
D111
C206
C207
R222
R221
R211
IC101
R218
R219
FB101
C203
R214
C204
R215
R202
R204
C201
C202
C209
FB103
C208
R213A
R212
C134
C135
R206
R205
IC102
R201
R213B
120574
R128-1
R128-2
R129-1
R129-2
R172-2
Q120 2
R127-1
R127-2
C126-1
R135 2
R137 2
R136 2
Q114-1
Q114-2
C120
R125 1
R124 1
R125-2
R124 2
R115-1
R115 2
R116-1
R116 2
C101 1
C101 2
R119-1
R119-2
R101 1
R101-2
R144-1
R144-2
C115-1
C115-2
C102-2
VERTICAL CIRCUIT BOARD

VERTICAL CIRCUIT BOARD
(Shown from foil side)

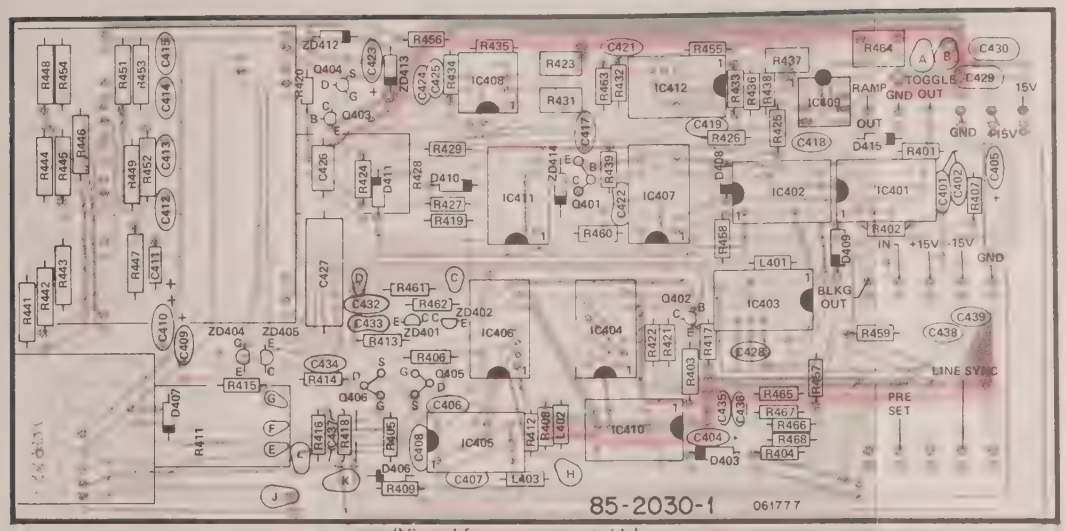


POWER SUPPLY CIRCUIT BOARD
(Viewed from component side)

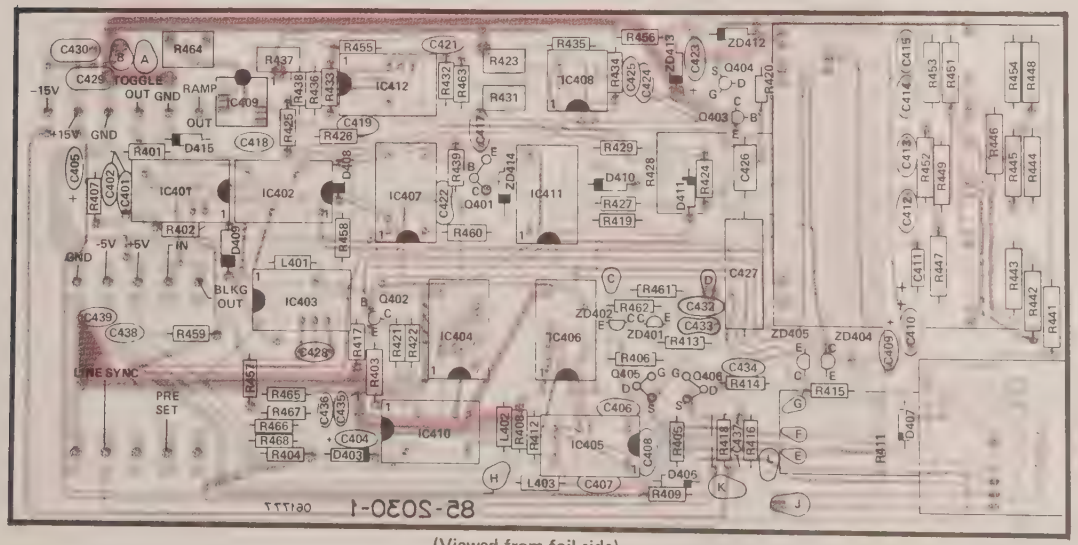


POWER SUPPLY CIRCUIT BOARD
(Viewed from foil side)

TIME BASE CIRCUIT BOARD

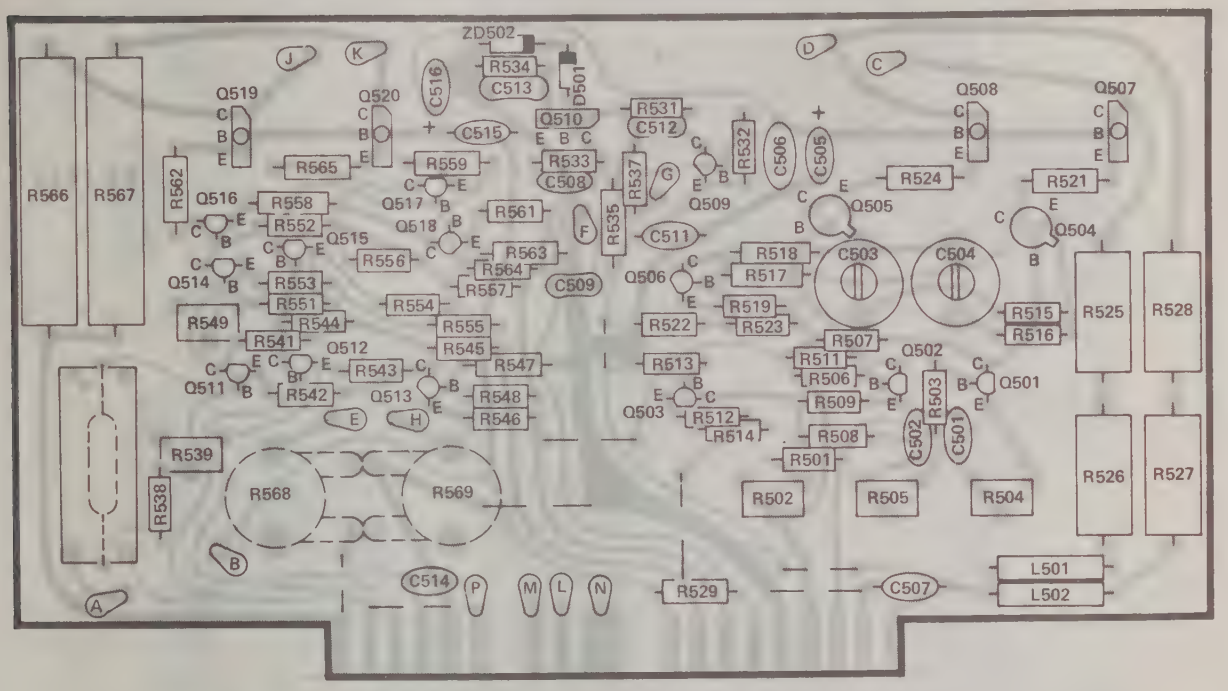


(Viewed from component side)

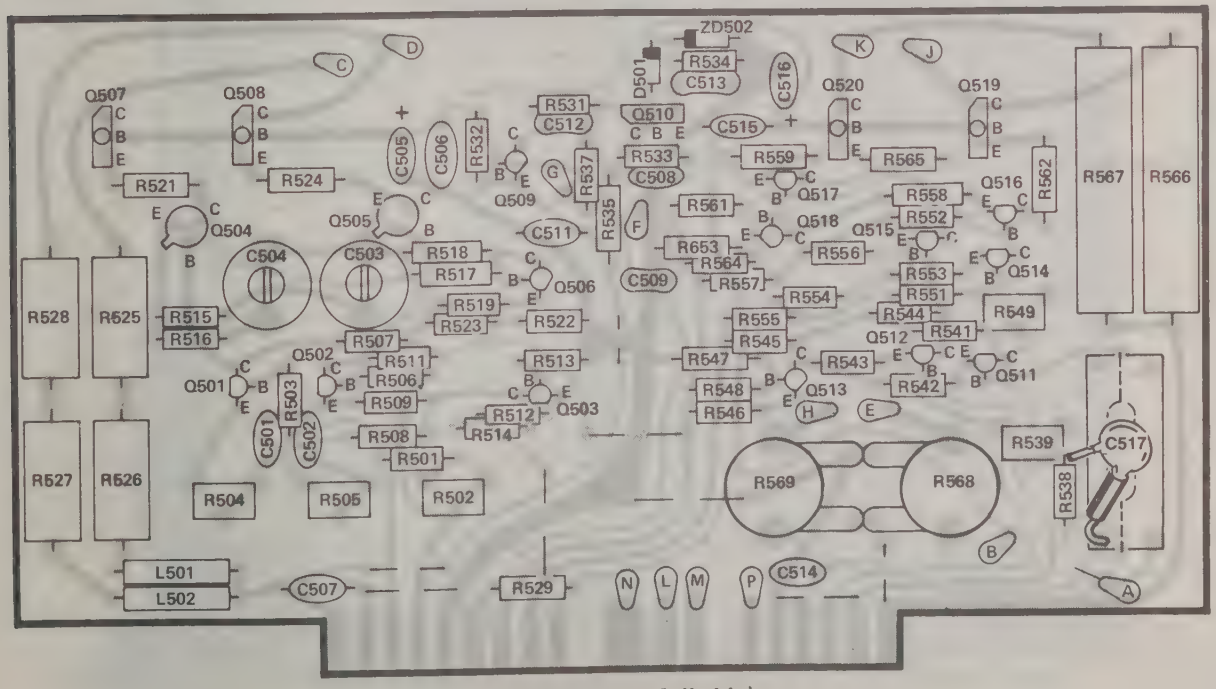


(Viewed from foil side)

DEFLECTION CIRCUIT BOARD

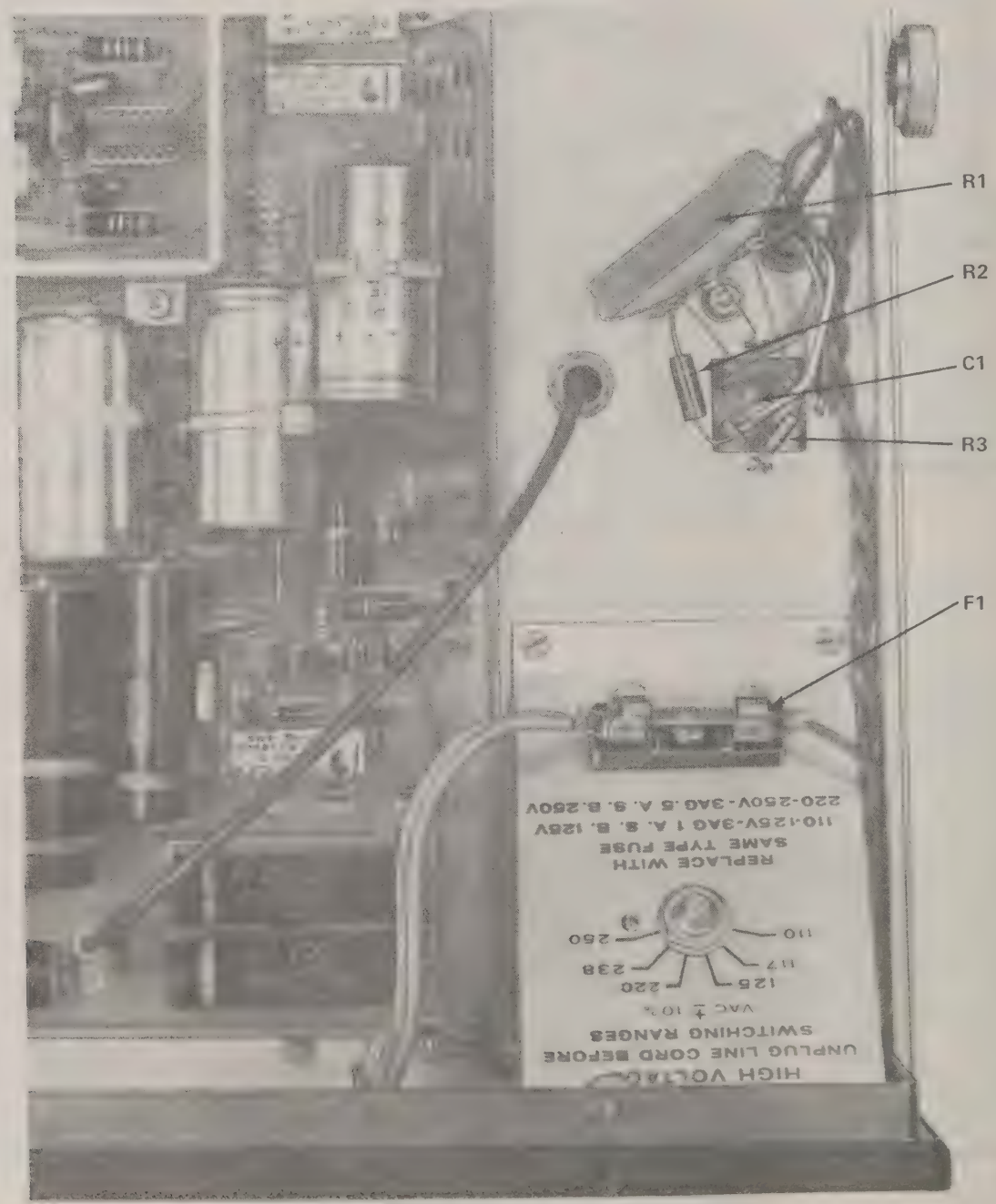


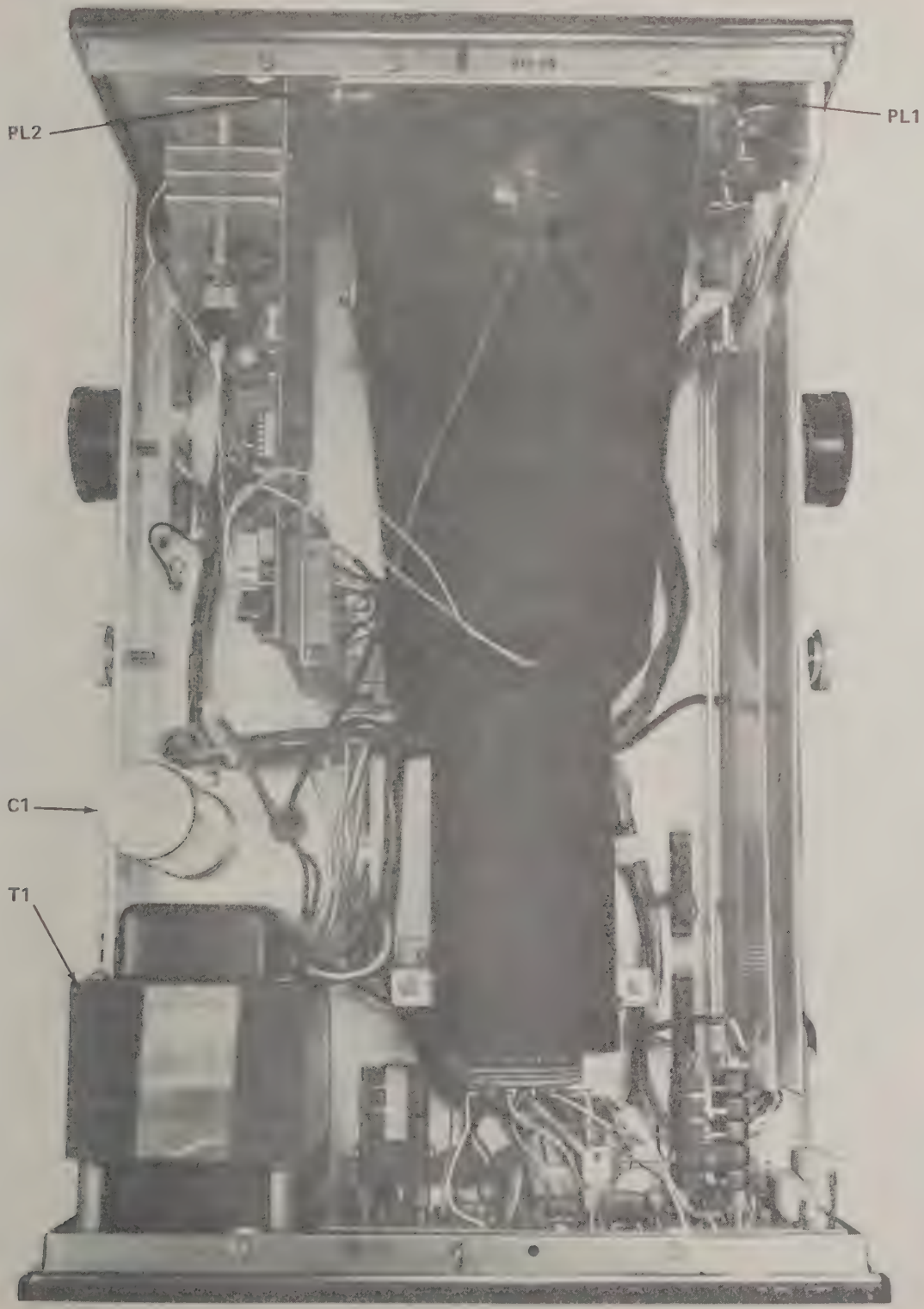
(Viewed from component side)



(Viewed from foil side)

CHASSIS PHOTOGRAPHS




PL2
PL1
C1
T1

COMPONENT PARTS

CHASSIS COMPONENTS

COMPONENT No.	HEATH Part No.	DESCRIPTION
R1	3-11-10	1500 Ω, 10%, 1-watt wire-wound
R2	1-43-1	51 Ω, 5%, 1-watt
R3	1-25	47 kΩ, 10%, 1/2-watt
C1	25-228	300-100-100 μF electrolytic
L1	40-1642	Trace rotation coil
T1	54-821	Transformer
S1	63-671	6-position rotary switch
V1	411-287	D13-47GH CRT
PL1	412-98	Lamp
PL2	412-98	Lamp
F1	421-23	1-ampere slow-blow fuse

VERTICAL CIRCUIT BOARD COMPONENTS

R101-1	1-57-12	33 Ω, 5%, 1/4-watt
R101-2	1-57-12	33 Ω, 5%, 1/4-watt
R102-1	2-45-11	999 kΩ, 1%, 1/8-watt
R102-2	2-45-11	999 kΩ, 1%, 1/8-watt
R103-1	2-15-11	1000 Ω, 1%, 1/8-watt
R103-2	2-15-11	1000 Ω, 1%, 1/8-watt
R104-1	2-44-11	990 kΩ, 1%, 1/8-watt
R104-2	2-44-11	990 kΩ, 1%, 1/8-watt
R105-1	2-40-11	10.1 kΩ, 1%, 1/8-watt
R105-2	2-40-11	10.1 kΩ, 1%, 1/8-watt
R106-1	2-43-11	900 kΩ, 1%, 1/8-watt
R106-2	2-43-11	900 kΩ, 1%, 1/8-watt
R107-1	2-42-11	111 kΩ, 1%, 1/8-watt
R107-2	2-42-11	111 kΩ, 1%, 1/8-watt
R108-1	2-28-11	61 Ω, 1%, 1/8-watt
R108-2	2-28-11	61 Ω, 1%, 1/8-watt
R109-1	2-30-11	124 Ω, 1%, 1/8-watt
R109-2	2-30-11	124 Ω, 1%, 1/8-watt
R110	NOT USED	
R111-1	2-35-11	254 Ω, 1%, 1/8-watt
R111-2	2-35-11	254 Ω, 1%, 1/8-watt
R112-1	2-36-11	720 Ω, 1%, 1/8-watt
R112-2	2-36-11	720 Ω, 1%, 1/8-watt
R113-1	2-38-11	1800 Ω, 1%, 1/8-watt
R113-2	2-38-11	1800 Ω, 1%, 1/8-watt
R114-1	1-84-12	100 kΩ, 5%, 1/4-watt
R114-2	1-84-12	100 kΩ, 5%, 1/4-watt

COMPONENT No.	HEATH Part No.	DESCRIPTION
Vertical Circuit Board Components (cont'd.)		
R115-1	1-57-12	33 Ω, 5%, 1/4-watt
R115-2	1-57-12	33 Ω, 5%, 1/4-watt
R116-1	2-96-12	1 MΩ, 1%, 1/4-watt
R116-2	2-96-12	1 MΩ, 1%, 1/4-watt
R117-1	1-66-12	560 Ω, 5%, 1/4-watt
R117-2	1-66-12	560 Ω, 5%, 1/4-watt
R118-1	2-68-12	20 kΩ, 1%, 1/4-watt
R118-2	2-68-12	20 kΩ, 1%, 1/4-watt
R119-1	10-975	500 Ω control
R119-2	10-975	500 Ω control
R120-1	1-87-12	1 MΩ, 5%, 1/4-watt
R120-2	1-87-12	1 MΩ, 5%, 1/4-watt
R121-1	2-68-12	20 kΩ, 1%, 1/4-watt
R121-2	2-68-12	20 kΩ, 1%, 1/4-watt
R122-1	1-66-12	560 Ω, 5%, 1/4-watt
R122-2	1-66-12	560 Ω, 5%, 1/4-watt
R123-1	1-55-12	10 Ω, 5%, 1/4-watt
R123-2	1-55-12	10 Ω, 5%, 1/4-watt
R124-1	1-94-12	18 kΩ, 5%, 1/4-watt
R124-2	1-94-12	18 kΩ, 5%, 1-4-watt
R125-1	1-94-12	18 kΩ, 5%, 1/4-watt
R125-2	1-94-12	18 kΩ, 5%, 1/4-watt
R126-1	1-55-12	10 Ω, 5%, 1/4-watt
R126-2	1-55-12	10 Ω, 5%, 1/4-watt
R127-1	2-33-11	220 Ω, 1%, 1/8-watt
R127-2	2-33-11	220 Ω, 1%, 1/8-watt
R128-1	63-669	1000 Ω control (Part of S102-1/R128-1/S105-1)
R128-2	63-669	1000 Ω control (Part of S102-2/R128-2/S105-2)
R129-1	10-966	50 Ω control
R129-2	10-966	50 Ω control
R130	NOT USED	
R131-1	2-38-11	1800 Ω, 1%, 1/8-watt
R131-2	2-38-11	1800 Ω, 1%, 1/8-watt
R132-1	2-19-11	825 Ω, 1%, 1/8-watt
R132-2	2-19-11	825 Ω, 1%, 1/8-watt
R133-1	2-19-11	825 Ω, 1%, 1/8-watt
R133-2	2-19-11	825 Ω, 1%, 1/8-watt
R134-1	2-38-11	1800 Ω, 1%, 1/8-watt
R134-2	2-38-11	1800 Ω, 1%, 1/8-watt
R135-1	2-4-11	236.8 Ω, 1%, 1/8-watt

COMPONENT No.	HEATH Part No.	DESCRIPTION
Vertical Circuit Board Components (cont'd.)		
R135-2	2-4-11	236.8 Ω, 1%, 1/8-watt
R136-1	2-41-11	13 kΩ, 1%, 1/8-watt
R136-2	2-41-11	13 kΩ, 1%, 1/8-watt
R137-1	2-12-11	2000 Ω, 1%, 1/8-watt
R137-2	2-12-11	2000 Ω, 1%, 1/8-watt
R138-1	1-58-12	47 Ω, 5%, 1/4-watt
R138-2	1-58-12	47 Ω, 5%, 1/4-watt
R139-1	1-75-12	3900 Ω, 5%, 1/4-watt
R139-2	1-75-12	3900 Ω, 5%, 1/4-watt
R140	NOT USED	
R141-1	1-75-12	3900 Ω, 5%, 1/4-watt
R141-2	1-75-12	3900 Ω, 5%, 1/4-watt
R142-1	1-58-12	47 Ω, 5%, 1/4-watt
R142-2	1-58-12	47 Ω, 5%, 1/4-watt
R143-1	1-55-12	10 Ω, 5%, 1/4-watt
R143-2	1-55-12	10 Ω, 5%, 1/4-watt
R144-1	1-55-12	10 Ω, 5%, 1/4-watt
R144-2	1-55-12	10 Ω, 5%, 1/4-watt
R145-1	1-55-12	10 Ω, 5%, 1/4-watt
R145-2	1-55-12	10 Ω, 5%, 1/4-watt
R146-1	2-38-11	1800 Ω, 1%, 1/8-watt
R146-2	2-38-11	1800 Ω, 1%, 1/8-watt
R147-1	2-27-11	47 Ω, 1%, 1/8-watt
R147-2	2-27-11	47 Ω, 1%, 1/8-watt
R148-1	19-188	250 Ω control (Part of R148-1/S103-1)
R148-2	19-188	250 Ω control (Part of R148-2/S103-2)
R149-1	2-27-11	47 Ω, 1%, 1/8-watt
R149-2	2-27-11	47 Ω, 1%, 1/8-watt
R150-1	10-917	200 Ω control
R150-2	10-917	200 Ω control
R151-1	2-38-11	1800 Ω, 1%, 1/8-watt
R151-2	2-38-11	1800 Ω, 1%, 1/8-watt
R152-1	2-4-11	236.8 Ω, 1%, 1/8-watt
R152-2	2-4-11	236.8 Ω, 1%, 1/8-watt
R153-1	2-41-11	13 kΩ, 1%, 1/8-watt
R153-2	2-41-11	13 kΩ, 1%, 1/8-watt
R154-1	2-12-11	2000 Ω, 1%, 1/8-watt
R154-2	2-12-11	2000 Ω, 1%, 1/8-watt
R155-1	1-55-12	10 Ω, 5%, 1/4-watt
R155-2	1-55-12	10 Ω, 5%, 1/4-watt
R156-1	1-65-12	470 Ω, 5%, 1/4-watt
R156-2	1-65-12	470 Ω, 5%, 1/4-watt
R157-1	10-339	2000 Ω control
R157-2	10-339	2000 Ω control
R158-1	1-55-12	10 Ω, 5%, 1/4-watt
R158-2	1-55-12	10 Ω, 5%, 1/4-watt
R159-1	1-55-12	10 Ω, 5%, 1/4-watt
R159-2	1-55-12	10 Ω, 5%, 1/4-watt

COMPONENT No.	HEATH Part No.	DESCRIPTION
Vertical Circuit Board Components (cont'd.)		
R160	NOT USED	
R161-1	1-55-12	10 Ω, 5%, 1/4-watt
R161-2	1-55-12	10 Ω, 5%, 1/4-watt
R162-1	1-75-12	3900 Ω, 5%, 1/4-watt
R162-2	1-75-12	3900 Ω, 5%, 1/4-watt
R163-1	1-75-12	3900 Ω, 5%, 1/4-watt
R163-2	1-75-12	3900 Ω, 5%, 1/4-watt
R164-1	1-55-12	10 Ω, 5%, 1/4-watt
R164-2	1-55-12	10 Ω, 5%, 1/4-watt
R165-1	1-55-12	10 Ω, 5%, 1/4-watt
R165-2	1-55-12	10 Ω, 5%, 1/4-watt
R166-1	2-29-11	100 Ω, 1%, 1/8-watt
R166-2	2-29-11	100 Ω, 1%, 1/8-watt
R167-1	2-29-11	100 Ω, 1%, 1/8-watt
R167-2	2-29-11	100 Ω, 1%, 1/8-watt
R168-1	1-72-12	2200 Ω, 5%, 1/4-watt
R168-2	1-72-12	2200 Ω, 5%, 1/4-watt
R169-1	1-60-12	100 Ω, 5%, 1/4-watt
R169-2	1-61-12	180 Ω, 5%, 1/4-watt
R170	10-390	20 kΩ control
R171-1	1-60-12	100 Ω, 5%, 1/4-watt
R171-2	1-61-12	180 Ω, 5%, 1/4-watt
R172-1	1-55-12	10 Ω, 5%, 1/4-watt
R172-2	1-55-12	10 Ω, 5%, 1/4-watt
R173-1	1-72-12	2200 Ω, 5%, 1/4-watt
R173-2	1-72-12	2200 Ω, 5%, 1/4-watt
R174-1	2-34-11	330 Ω, 1%, 1/8-watt
R174-2	2-34-11	330 Ω, 1%, 1/8-watt
R175-1	1-37-12	150 Ω, 10%, 1/4-watt
R175-2	1-37-12	150 Ω, 10%, 1/4-watt
R176-1	10-917	200 Ω control
R176-2	10-917	200 Ω control
R177-1	2-41-11	13 kΩ, 1%, 1/8-watt
R177-2	2-41-11	13 kΩ, 1%, 1/8-watt
R178-1	2-12-11	2000 Ω, 1%, 1/8-watt
R178-2	2-12-11	2000 Ω, 1%, 1/8-watt
R179-1	2-12-11	2000 Ω, 1%, 1/8-watt
R179-2	2-12-11	2000 Ω, 1%, 1/8-watt
R180	NOT USED	
R181-1	2-41-11	13 kΩ, 1%, 1/8-watt
R181-2	2-41-11	13 kΩ, 1%, 1/8-watt
R182-1	1-69-12	1000 Ω, 5%, 1/4-watt
R182-2	1-69-12	1000 Ω, 5%, 1/4-watt
R183	1-55-12	10 Ω, 5%, 1/4-watt
R184	2-19-11	825 Ω, 1%, 1/8-watt
R185	1-69-12	1000 Ω, 5%, 1/4-watt
R186	2-19-11	825 Ω, 1%, 1/8-watt
R187	1-55-12	10 Ω, 5%, 1/4-watt
R188	1-58-12	47 Ω, 5%, 1/4-watt
R189	1-71-12	1500 Ω, 5%, 1/4-watt

COMPONENT No.	HEATH Part No.	DESCRIPTION
Vertical Circuit Board Components (cont'd.)		
R190	NOT USED	
R191	1-71-12	1500 Ω, 5%, 1/4-watt
R192	1-58-12	47 Ω, 5%, 1/4-watt
R193	1-143	2.7 Ω, 5%, 1/2-watt
R194	1-143	2.7 Ω, 5%, 1/2-watt
R195	NOT USED	
R196	1-143	2.7 Ω, 5%, 1/2-watt
R197	1-143	2.7 Ω, 5%, 1/2-watt
R198	1-43	2.7 Ω, 5%, 1/2-watt
R199	NOT USED	
R200	NOT USED	
R201	1-62-12	220 Ω, 5%, 1/4-watt
R202	1-69-12	1000 Ω, 5%, 1/4-watt
R203	1-62-12	220 Ω, 5%, 1/4-watt
R204	1-69-12	1000 Ω, 5%, 1/4-watt
R205	1-70-12	1200 Ω, 5%, 1/4-watt
R206	1-70-12	1200 Ω, 5%, 1/4-watt
R207	2-38-11	1800 Ω, 1%, 1/8-watt
R208	2-15-11	1000 Ω, 1%, 1/8-watt
R209	2-32-11	200 Ω, 1%, 1/8-watt
R210	NOT USED	
R211	1-97-12	2400 Ω, 5%, 1/4-watt
R212	1-78-12	6800 Ω, 5%, 1/4-watt
R213A	63-673	1000 Ω control (Part of S103/R213 A/B)
R213B	63-673	1000 Ω control (Part of S103/R213 A/B)
R214	1-71-12	1500 Ω, 5%, 1/4-watt
R215	1-69-12	1000 Ω, 5%, 1/4-watt
R216	1-63-12	270 Ω, 5%, 1/4-watt
R217	1-63-12	270 Ω, 5%, 1/4-watt
R218	1-63-12	270 Ω, 5%, 1/4-watt
R219	1-63-12	270 Ω, 5%, 1/4-watt
R220	NOT USED	
R221	1-76-12	4700 Ω, 5%, 1/4-watt
R222	1-76-12	4700 Ω, 5%, 1/4-watt
R223	1-79	820 Ω, 5%, 1/2-watt
R224	1-79	820 Ω, 5%, 1/2-watt
C101-1	27-132	.1 μF Mylar*
C101-2	27-132	.1 μF Mylar
C102-1	31-57	2.7-20 pF trimmer
C102-2	31-57	2.7-20 pF trimmer
C103	NOT USED	
C104-1	31-58	1.7-10 pF trimmer
C104-2	31-58	1.7-10 pF trimmer
C105-1	21-141	.0033 μF ceramic
C105-2	21-141	.0033 μF ceramic
C106-1	31-57	2.7-20 pF trimmer

*Registered Trademark, DuPont.

COMPONENT No.	HEATH Part No.	DESCRIPTION
Vertical Circuit Board Components (cont'd.)		
C106-2	31-57	2.7-20 pF trimmer
C107	NOT USED	
C108-1	31-58	1.7-10 pF trimmer
C108-2	31-58	1.7-10 pF trimmer
C109-1	20-113	470 pF mica
C109-2	20-113	470 pF mica
C110	NOT USED	
C111-1	31-57	2.7-20 pF trimmer
C111-2	31-57	2.7-20 pF trimmer
C112	NOT USED	
C113-1	31-58	1.7-10 pF trimmer
C113-2	31-58	1.7-10 pF trimmer
C114-1	20-97	50 pF mica
C114-2	20-97	50 pF mica
C115-1	31-58	1.7-10 pF trimmer
C115-2	31-58	1.7-10 pF trimmer
C116-1	20-105	180 pF mica
C116-2	20-105	180 pF mica
C117-1	20-148	1000 pF mica
C117-2	20-148	100 pF mica
C118-1	20-174	42 pF mica
C118-2	20-174	42 pF mica
C119-1	20-130	12 pF mica
C119-2	20-130	12 pF mica
C120-1	NOT USED	
C120-2	21-16	.01 μF ceramic
C121-1	21-16	.01 μF ceramic
C122-1	25-221	2.2 μF tantalum
C122-2	25-221	2.2 μF tantalum
C123-1	25-221	2.2 μF tantalum
C123-2	25-221	2.2 μF tantalum
C124-1	27-47	.1 μF Mylar
C124-2	27-47	.1 μF Mylar
C125-1	25-220	10 μF tantalum
C125-2	25-220	10 μF tantalum
C126-1	31-36	8-50 pF trimmer
C126-2	31-36	8-50 pF trimmer
C127-1	20-108	200 pF mica
C127-2	20-149	150 pF mica
C128-1	20-110	75 pF mica
C128-2	20-110	75 pF mica
C129	27-47	.1 μF Mylar
C130	NOT USED	
C131	27-47	.1 μF Mylar
C132	25-223	47 μF tantalum
C133	25-223	47 μF tantalum
C134	25-117	100 μF electrolytic
C135	21-143	.05 μF ceramic
C136	25-56	100 μF electrolytic
C137	27-47	.1 μF Mylar

COMPONENT No.	HEATH Part No.	DESCRIPTION
Vertical Circuit Board Components (cont'd.)		
C138	27-47	.1 μF Mylar
C201	25-221	2.2 μF tantalum
C202	25-221	2.2 μF tantalum
C203	25-212	22 μF tantalum
C204	25-212	22 μF tantalum
C205	25-223	47 μF tantalum
C206	20-139	330 pF mica
C207	20-139	330 pF mica
C208	25-115	10 μF electrolytic
C209	25-115	10 μF electrolytic
D101-1	417-854	SF50077 diode
D102-1	417-854	SF50077 diode
D101-2	417-854	SF50077 diode
D102-2	417-854	SF50077 diode
ZD103-1	56-85	SZ5, 20 mA, 5V zener
ZD1-3-2	56-85	SZ5, 20 mA, 5V zener
ZD104-1	56-85	SZ5, 20 mA, 5V zener
ZD104-2	56-85	SZ5, 20 mA, 5V zener
D105-1	56-56	1N4149, 10 mA, 75V silicon
D105-2	56-56	1N4149, 10 mA, 75V silicon
D106-1	56-56	1N4149, 10 mA, 75V silicon
D106-2	56-56	1N4149, 10 mA, 75V silicon
D107-1	56-56	1N4149, 10 mA, 75V silicon
D107-2	56-56	1N4149, 10 mA, 75V silicon
D108-1	56-56	1N4149, 10 mA, 75V silicon
D108-2	56-56	1N4149, 10 mA, 75V silicon
D109-1	56-56	1N4149, 10 mA, 75V silicon
D109-2	56-56	1N4149, 10 mA, 75V silicon
D110-1	56-56	1N4149, 10 mA, 75V silicon
D110-2	56-56	1N4149, 10 mA, 75V silicon
D111	56-56	1N4149, 10 mA, 75V silicon
D112	56-56	1N4149, 10 mA, 75V silicon

COMPONENT No.	HEATH Part No.	DESCRIPTION
Vertical Circuit Board Components (cont'd.)		
Q101A-1/ Q101B-1	417-853	SF83045
Q101A-2/ Q101B-2	417-853	SF83045
Q102-1	417-292	2N5771
Q102-2	417-292	2N5771
Q103-1	417-292	2N5771
Q103-2	417-292	2N5771
Q104-1	417-235	2N4121
Q104-2	417-235	2N4121
Q105-1	417-235	2N4121
Q105-2	417-235	2N4121
Q106-1	417-293	2N5770
Q106-2	417-293	2N5770
Q107-1	417-293	2N5770
Q107-2	417-293	2N5770
Q108-1	417-134	MPS6520
Q108-2	417-134	MPS6520
Q109-1	417-134	MPS6520
Q109-2	417-134	MPS6520
Q110-1	417-292	2N5771
Q110-2	417-292	2N5771
Q111-1	417-292	2N5771
Q111-2	417-292	2N5771
Q112	417-293	2N5770
Q113	417-293	2N5770
Q114-1	417-235	2N4121
Q114-2	417-235	2N4121
Q115-1	417-118	2N3393
Q115-2	417-118	2N3393
Q116-1	417-235	2N4121
Q116-2	417-235	2N4121
Q117-1	417-235	2N4121
Q117-2	417-235	2N4121
Q118-1	417-235	2N4121
Q118-2	417-235	2N4121
Q119-1	417-235	2N4121
Q119-2	417-235	2N4121
Q-120-1	417-801	MPS-A20
Q120-2	417-801	MPS-A20
Q121	417-235	2N4121
Q122	417-235	2N4121
Q123	417-293	2N5770
IC101	443-5	SN7473N
IC102	443-1	SN7400N

COMPONENT No.	HEATH Part No.	DESCRIPTION
Vertical Circuit Board Components (cont'd.)		
S101-1	61-20	Toggle switch
S101-2	61-20	Toggle switch
S102-1	63-669	12-position rotary switch (Part of S102-1/R128-1/S105-1)
S102-2	63-669	12-position rotary switch (Part of S102-2/R128-2/S105-2)
S103-1	19-188	Switch (Part of R148-1/S103-1)
S103-2	19-188	Switch (Part of R148-2/S103-2)
S104	63-673	3-position rotary switch (Part of S104/R213A/B)
S105-1	63-669	12-position rotary switch (Part of S102-1/R128-1/S105-1)
S105-2	63-669	12-position rotary switch (Part of S102-2/R128-2/S105-2)
FB101	475-11	Ferrite inductor
FB102	475-11	Ferrite inductor
FB103	475-11	Ferrite inductor
FB104-1	475-10	Ferrite bead
FB104-2	475-10	Ferrite bead
FB105-1	475-10	Ferrite bead
FB105-2	475-10	Ferrite bead
TIME BASE CIRCUIT BOARD COMPONENTS		
R401	1-69-12	1000 Ω, 5%, 1/4-watt
R402	1-69-12	1000 Ω, 5%, 1/4-watt
R403	1-129	4.7 Ω, 10%, 1/2-watt
R404	1-83-12	47 kΩ, 5%, 1/4-watt
R405	1-69-12	1000 Ω, 5%, 1/4-watt
R406	1-87-12	1 MΩ, 5%, 1/4-watt
R407	1-55-12	10 Ω, 5%, 1/4-watt
R408	1-115-12	51 Ω, 5%, 1/4-watt
R409	1-63-12	270 Ω, 5%, 1/4-watt
R410	NOT USED	
R411	63-672	100 Ω control (Part of S402/R411/S404)
R412	1-76-12	4700 Ω, 5%, 1/4-watt
R413	1-84-12	100 kΩ, 5%, 1/4-watt
R414	1-103-12	150 Ω, 5%, 1/4-watt
R415	1-63-12	270 Ω, 5%, 1/4-watt
R416	1-87-12	1 MΩ, 5%, 1/4-watt
R417	1-83-12	47 kΩ, 5%, 1/4-watt
R418	1-103-12	150 Ω, 5%, 1/4-watt
R419	1-83-12	47 kΩ, 5%, 1/4-watt

COMPONENT No.	HEATH Part No.	DESCRIPTION
Time Base Circuit Board Components (cont'd.)		
R420	1-6-12	3300 Ω, 10%, 1/4-watt
R421	1-69-12	1000 Ω, 5%, 1/4-watt
R422	1-65-12	470 Ω, 5%, 1/4-watt
R423	10-917	200 Ω control
R424	1-80-12	10 kΩ, 5%, 1/4-watt
R425	1-58-12	47 Ω, 5%, 1/4-watt
R426	1-58-12	47 Ω, 5%, 1/4-watt
R427	1-65-12	470 Ω, 5%, 1/4-watt
R428	63-670	200 Ω control (Part of S401/R428/S403)
R429	1-55-12	10 Ω, 5%, 1/4-watt
R430	NOT USED	
R431	10-917	200 Ω control
R432	1-108-12	15 kΩ, 5%, 1/4-watt
R433	1-108-12	15 kΩ, 5%, 1/4-watt
R434	1-58-12	47 Ω, 5%, 1/4-watt
R435	1-58-12	47 Ω, 5%, 1/4-watt
R436	1-63-12	270 Ω, 5%, 1/4-watt
R437	10-949	300 Ω control
R438	1-60-12	100 Ω, 5%, 1/4-watt
R439	1-64-12	390 Ω, 5%, 1/4-watt
R440	NOT USED	
R441	2-671-12	1.6 MΩ, 5%, 1/4-watt
R442	2-95-12	800 kΩ, 1%, 1/4-watt
R443	2-672-12	400 kΩ, 1%, 1/4-watt
R444	2-673-12	160 kΩ, 1%, 1/4-watt
R445	2-665-12	80 kΩ, 1%, 1/4-watt
R446	2-674-12	40 kΩ, 1%, 1/4-watt
R447	2-675-12	16 kΩ, 1%, 1/4-watt
R448	2-676-12	8000 Ω, 1%, 1/4-watt
R449	2-677-12	4000 Ω, 1%, 1/4-watt
R450	NOT USED	
R451	2-678-12	1600 Ω, 1%, 1/4-watt
R452	2-679-12	320 kΩ, 1%, 1/4-watt
R453	2-680-12	32 kΩ, 1%, 1/4-watt
R454	2-682-12	3200 Ω, 1%, 1/4-watt
R455	1-60-12	100 Ω, 5%, 1/4-watt
R456	1-103-12	150 Ω, 5%, 1/4-watt
R457	1-65-12	470 Ω, 5%, 1/4-watt
R458	1-69-12	1000 Ω, 5%, 1/4-watt
R459	1-69-12	1000 Ω, 5%, 1/4-watt
R460	1-83-12	47 kΩ, 5%, 1/4-watt
R461	1-104	100 kΩ, 5%, 1/2-watt
R462	1-104	100 kΩ, 5%, 1/4-watt
R463	1-60-12	100 Ω, 5%, 1/2-watt
R464	10-339	2000 Ω control
R465	1-77-12	5600 Ω, 5%, 1/4-watt
R466	1-76-12	4700 Ω, 5%, 1/4-watt
R467	1-75-12	3900 Ω, 5%, 1/4-watt
R468	1-76-12	4700 Ω, 5%, 1/4-watt

Time Base Circuit Board Components (cont'd.)

COMPONENT No.	HEATH Part No.	DESCRIPTION
C401	21-46	.005 µF ceramic
C402	21-46	.005 µF ceramic
C403	NOT USED	
C404	25-220	10 µF tantalum
C405	25-223	47 µF tantalum
C406	21-96	.1 µF ceramic
C407	21-96	.1 µF ceramic
C408	21-96	.1 µF ceramic
C409	25-212	22 µF tantalum
C410	25-221	2.2 µF tantalum
C411	25-210	.22 µF tantalum
C412	21-84	.05 µF ceramic
C413	21-36	.002 µF ceramic
C414	21-31	200 pF ceramic
C415	21-101	56 pF ceramic
C416	NOT USED	
C417	21-47	.01 µF ceramic
C418	21-47	.01 µF ceramic
C419	21-47	.01 µF ceramic
C420	NOT USED	
C421	21-96	.1 µF ceramic
C422	20-121	390 pF mica
C423	25-223	47 µF tantalum
C424	21-47	.01 µF ceramic
C425	21-47	.01 µF ceramic
C426	29-26	.00125 µF polystyrene
C427	29-27	2.5 µF polystyrene
C428	21-36	.002 µF ceramic
C429	21-47	.1 µF Mylar
C430	21-47	.1 µF Mylar
C431	NOT USED	
C432	21-16	.01 µF, 500V ceramic
C433	20-102	100 pF mica
C434	21-47	.01 µF ceramic
C435	21-47	.01 µF ceramic
C436	21-47	.01 µF ceramic
C437	21-47	.01 µF ceramic
C438	21-96	.1 µF ceramic
C439	21-96	.1 µF ceramic
ZD401	417-118	2N3393 transistor
ZD402	417-118	2N3393 transistor
D403	56-56	1N4149, 10 mA, 75V silicon
ZD404	417-118	2N3393 transistor
ZD405	417-118	2N3393 transistor
D406	56-56	1N4149, 10 mA, 75V silicon
D407	56-56	1N4149, 10 mA, 75V silicon

Time Base Circuit Board Components (cont'd.)

COMPONENT No.	HEATH Part No.	DESCRIPTION
D408	56-56	1N4149, 10 mA, 75V silicon
D409	56-56	1N4149, 10 mA, 75V silicon
D410	56-56	1N4149, 10 mA, 75V silicon
D411	56-74	MZ2362, 100 mA, 2.1V zener
ZD412	56-16	1N751, 20 mA, 5.1V zener
ZD413	56-16	1N751, 20 mA, 5.1V zener
ZD414	56-31	PS18775, 20 mA, 6.8V zener
D415	56-56	1N4149, 10 mA, 75V silicon
Q401	417-235	2N4121
Q402	417-118	2N3393
Q403	417-292	2N5771
Q404	417-806	TIS75
Q405 Q406	417-812	E421
IC401	443-1	SN7400N
IC402	443-1	SN7400N
IC403	443-1	SN7400N
IC404	443-6	SN7474N
IC405	442-50	µ760
IC406	443-12	SN7410N
IC407	443-1	SN7400N
IC408	442-82	N5741V
IC409	442-648	LM310N
IC410	443-23	SN74122N
IC411	443-23	SN74122N
IC412	442-50	µ760
S401	63-670	22-position rotary switch (Part of S401/ R428/S403)
S402	63-672	8-position rotary switch (Part of S402/ R411/S404)
S403	63-670	22-position rotary switch (Part of S401/ R428/S403)
S404	63-672	8-position rotary switch (Part of S402/ R411/S404)
L401	45-73	2.2 µH
L402	45-73	2.2 µH
L403	45-73	2.2 µH

COMPONENT No.	HEATH Part No.	DESCRIPTION
DEFLECTION CIRCUIT BOARD COMPONENTS		
R501	1-60-12	100 Ω, 5%, 1/4-watt
R502	10-918	500 Ω control
R503	1-60-12	100 Ω, 5%, 1/4-watt
R504	10-386	10 kΩ control
R505	10-390	20 kΩ control
R506	1-60-12	100 Ω, 5%, 1/4-watt
R507	1-117-12	510 Ω, 5%, 1/4-watt
R508	1-59-12	56 Ω, 5%, 1/4-watt
R509	1-59-12	56 Ω, 5%, 1/4-watt
R510	NOT USED	
R511	1-117-12	510 Ω, 5%, 1/4-watt
R512	1-61-12	180 Ω, 5%, 1/4-watt
R513	1-67-12	680 Ω, 5%, 1/4-watt
R514	1-68-12	820 Ω, 5%, 1/4-watt
R515	1-57-12	33 Ω, 5%, 1/4-watt
R516	1-60-12	100 Ω, 5%, 1/4-watt
R517	1-161	91 Ω, 5%, 1/2-watt
R518	1-161	91 Ω, 5%, 1/2-watt
R519	1-57-12	33 Ω, 5%, 1/4-watt
R520	NOT USED	
R521	1-49	22 Ω, 10%, 1/2-watt
R522	1-70-12	1200 Ω, 5%, 1/4-watt
R523	1-63-12	270 Ω, 5%, 1/4-watt
R524	1-49	22 Ω, 10%, 1/2-watt
R525	1-12-2	470 Ω, 10%, 2-watt
R526	1-12-2	470 Ω, 10%, 2-watt
R527	1-12-2	470 Ω, 10%, 2-watt
R528	1-12-2	470 Ω, 10%, 2-watt
R529	1-69-12	1000 Ω, 5%, 1/4-watt
R530	NOT USED	
R531	1-69-12	1000 Ω, 5%, 1/4-watt
R532	1-69-12	1000 Ω, 5%, 1/4-watt
R533	1-69-12	1000 Ω, 5%, 1/4-watt
R534	1-64-12	390 Ω, 5%, 1/4-watt
R535	1-162	18 kΩ, 5%, 1/2-watt
R536	NOT USED	
R537	1-60-12	100 Ω, 5%, 1/4-watt
R538	1-58-12	47 Ω, 5%, 1/4-watt
R539	10-314	100 Ω control
R540	NOT USED	
R541	1-65-12	470 Ω, 5%, 1/4-watt
R542	1-116-12	240 Ω, 5%, 1/4-watt
R543	1-116-12	240 Ω, 5%, 1/4-watt
R544	1-65-12	470 Ω, 5%, 1/4-watt
R545	1-64-12	390 Ω, 5%, 1/4-watt
R546	1-64-12	390 Ω, 5%, 1/4-watt
R547	1-68-12	820 Ω, 5%, 1/4-watt
R548	1-67-12	680 Ω, 5%, 1/4-watt
R549	10-904	5000 Ω control

COMPONENT No.	HEATH Part No.	DESCRIPTION
Deflection Circuit Board Components (cont'd.)		
R550	NOT USED	
R551	1-65-12	1000 Ω, 5%, 1/4-watt
R552	1-118-12	620 Ω, 5%, 1/4-watt
R553	1-92-12	330 Ω, 5%, 1/4-watt
R554	1-92-12	330 Ω, 5%, 1/4-watt
R555	1-105-12	200 Ω, 5%, 1/4-watt
R556	1-118-12	620 Ω, 5%, 1/4-watt
R557	1-43-12	120 Ω, 10%, 1/4-watt
R558	1-137	200 Ω, 5%, 1/2-watt
R559	1-137	200 Ω, 5%, 1/2-watt
R560	NOT USED	
R561	1-115-12	51 Ω, 5%, 1/4-watt
R562	1-49	22 Ω, 10%, 1/2-watt
R563	1-69-12	1000 Ω, 5%, 1/4-watt
R564	1-116-12	240 Ω, 5%, 1/4-watt
R565	1-49	22 Ω, 10%, 1/2-watt
R566	3-2-7	3750 Ω, 10%, 7-watt
R567	3-2-7	3750 Ω, 10%, 7-watt
R568	10-384	500 Ω control
R569	10-384	500 Ω control
C501	21-21	200 pF ceramic
C502	21-147	47 pF ceramic
C503	21-96	6-60 pF trimmer
C504	21-96	6-60 pF trimmer
C505	25-223	47 µF tantalum
C506	21-31	.02 µF ceramic
C507	21-31	.02 µF ceramic
C508	21-46	.005 µF ceramic
C509	20-111	220 pF mica
C510	NOT USED	
C511	21-31	.02 µF ceramic
C512	20-107	680 pF mica
C513	20-103	1000 pF mica
C514	21-143	.05 µF ceramic
C515	21-31	.02 µF ceramic
C516	25-223	47 µF tantalum
C517	21-121	56 pF ceramic
D501	56-56	1N4149, 10 mA, 75V silicon
ZD502	56-88	ZVP-86, 86V zener
Q501	417-292	2N5771
Q502	417-292	2N5771
Q503	417-235	2N4121
Q504	417-154	2N2369
Q505	417-154	2N2369
Q506	417-237	SE8020
Q507	417-245	D40N1
Q508	417-245	D40N1

COMPONENT No.	HEATH Part No.	DESCRIPTION
Deflection Circuit Board Components (cont'd.)		
Q509	417-805	2N4889
Q510	417-245	D40N1
Q511	417-293	2N5770
Q512	417-293	2N5770
Q513	417-237	SE6020
Q514	417-292	2N5771
Q515	417-292	2N5771
Q516	417-293	2N5770
Q517	417-293	2N5770
Q518	417-237	SE6020
Q519	417-245	D40N1
Q520	417-245	D40N1
FB501	475-16	Ferrite bead
FB502	475-16	Ferrite bead
FB503	475-16	Ferrite bead
FB504	475-16	Ferrite bead
L501	45-39	4.65 μH
L502	45-39	4.65 μH
CONTROL CIRCUIT BOARD COMPONENTS		
R601	1-33-1	680 kΩ, 10%, 1-watt
R602	10-948	250 kΩ control
R603	1-185	180 kΩ, 5%, 1/2-watt
R604	1-50	62 kΩ, 1/2-watt
R605	10-947	500 kΩ control
R606	1-59	220 kΩ, 5%, 1/2-watt
R607	3-33-5	10 Ω, 10%, 5-watt wire-wound
R608	19-182	50 Ω control (Part of R608/S601)
R609	1-1	47 Ω, 10%, 1/2-watt
ZD601	56-68	ZVR-68, 68V zener
S601	19-182	Switch (Part of R608/S601)
PL601	412-31	Lamp
POWER SUPPLY CIRCUIT BOARD COMPONENTS		
R701	1-36-2	2.2 MΩ, 10%, 2-watt
R702	1-107	150 kΩ, 5%, 1/2-watt
R703	1-123	100 Ω, 5%, 1/2-watt
R704	1-124	27 kΩ, 5%, 1/2-watt
R705	10-388	20 kΩ control
R706	1-133	15 kΩ, 5%, 1/2-watt
R707	1-36	1.5 MΩ, 10%, 1/2-watt
R708	1-37	2.2 MΩ, 10%, 1/2-watt
R709	1-25	47 kΩ, 10%, 1/2-watt
R710	NOT USED	

COMPONENT No.	HEATH Part No.	DESCRIPTION
Power Supply Circuit Board Components (cont'd.)		
R711	3-2-2	.33 Ω, 5%, 2-watt
R712	3-2-2	.33 Ω, 5%, 2-watt
R713	1-123	100 Ω, 5%, 1/2-watt
R714	1-123	100 Ω, 5%, 1/2-watt
R715	1-172	1000 Ω, 5%, 1/2-watt
R716	3-7-2	1 Ω, 10%, 2-watt
R717	1-123	100 Ω, 5%, 1/2-watt
R718	1-26-2	4.7 Ω, 10%, 2-watt
R719	1-123	100 Ω, 5%, 1/2-watt
R720	NOT USED	
R721	1-133	15 kΩ, 5%, 1/2-watt
R722	10-386	10 kΩ control
R723	1-22	22 kΩ, 5%, 1/2-watt
R724	1-34-1	1 MΩ, 10%, 1-watt
R725	1-36-2	2.2 MΩ, 10%, 2-watt
R726	1-34-1	1 MΩ, 10%, 1-watt
C701	21-16	.01 μF ceramic
C702	21-31	.02 μF ceramic
C703	NOT USED	
C704	25-215	2 μF electrolytic
C705	27-19	1 μF Mylar
C706	23-104	.5 μF paper
C707	23-104	.5 μF paper
C708	23-101	.015 μF paper
C709	23-101	.015 μF paper
C710	23-101	.015 μF paper
C711	23-101	.015 μF paper
C712	25-241	1200 μF electrolytic
C713	25-241	1200 μF electrolytic
C714	27-47	.1 μF Mylar
C715	27-47	.1 μF Mylar
C716	27-19	1 μF Mylar
C717	27-19	1 μF Mylar
C718	25-154	2500 μF electrolytic
C719	25-154	2500 μF electrolytic
C720	25-272	6000 μF electrolytic
C721	25-272	6000 μF electrolytic
C722	25-272	6000 μF electrolytic
C723	25-230	2000 μF electrolytic
D701	57-27	1N2071, 1A, 600V silicon
ZD702	56-48	BZT110A, 110V zener
ZD703	56-48	BZT110A, 110V zener
ZD704	56-68	ZVR-68, 68V zener
D705	57-27	1N2071, 1A, 600V silicon
D706	57-27	1N2071, 1A, 600V silicon
D707	57-27	1N2071, 1A, 600V silicon

COMPONENT No.	HEATH Part No.	DESCRIPTION
Power Supply Circuit Board Components (cont'd.)		
D708	57-52	1N2071, 1A, 600V silicon
D709	57-56	3 mA, 3000V silicon
D710	57-56	3 mA, 3000V silicon
D711	57-56	3 mA, 3000V silicon
D712	57-27	1N2071, 1A, 600V silicon
D713		
D714		
D715		
D716		
D717		
D718		
D719		
D720		
D721		
D722		
D723		
D724		
ZD725	56-58	1N709A (violet-black-white) 6.2V zener
ZD726	56-58	1N709A (violet-black-white) 6.2V zener

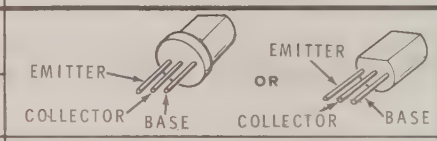
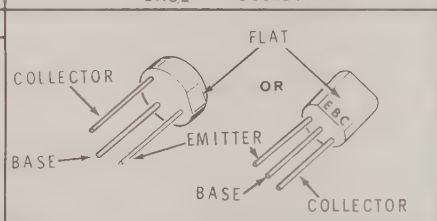
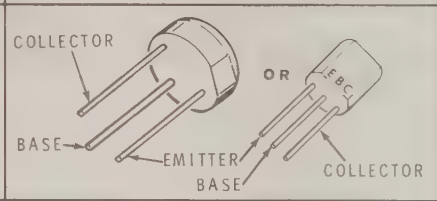
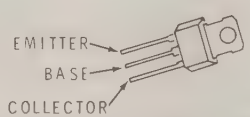
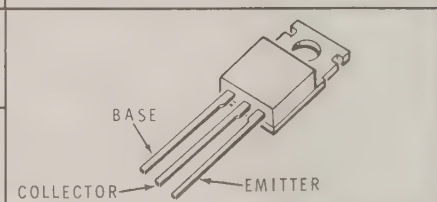
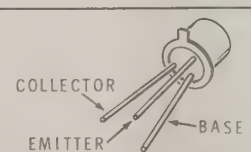
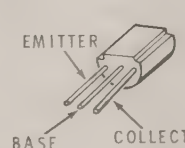
COMPONENT No.	HEATH Part No.	DESCRIPTION
Power Supply Circuit Board Components (cont'd.)		
Q701	417-118	2N3393
Q702	417-834	MPSU10
Q703	417-289	2N6109
Q704	417-296	TA7311
Q705	417-118	2N3393
Q706	417-224	MPSU05
Q707	417-201	X29A829
Q708	417-234	2N3638A
IC701	442-65	SG4501N

IDENTIFICATION CHARTS

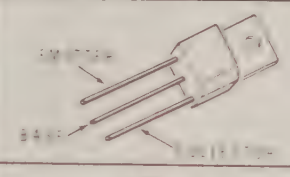
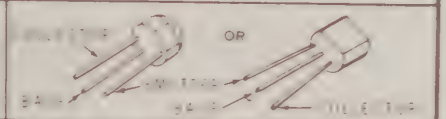
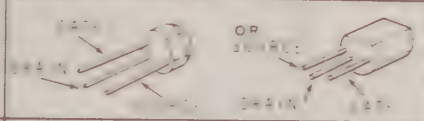
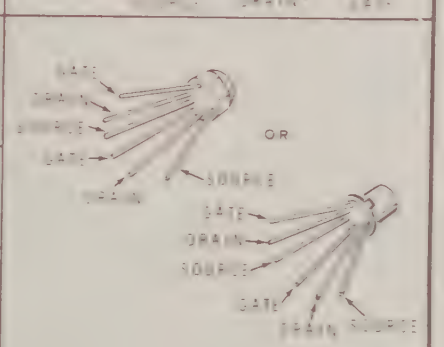
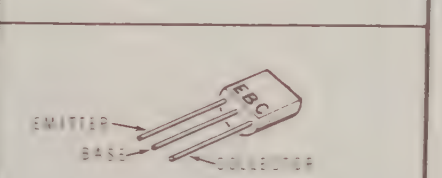
DIODES

DIODES	HEATH PART NUMBER	MAY BE REPLACED BY	DESCRIPTION	BASING DIAGRAM
ZD502, ZD601 ZD704	56-68	ZVR-68	ZENER DIODE 7mA 68V	NOTE: HEATH PART NUMBER MAY BE STAMPED ON MOST DIODES
ZD702, ZD703	56-48	BZT110A	ZENER DIODE 8.8mA 110V	
ZD725 ZD726	56-58	1N709A (VIOLET-BLACK-WHITE)	ZENER DIODE 25mA 6.0V	
ZD412 ZD413	56-16	1N751 (VIOLET-GREEN-BROWN)	ZENER DIODE 20mA 5.1V	
ZD414	56-31	P818775	ZENER DIODE 20mA 6.8V	
ZD103-1, ZD103-2 ZD104-1, ZD104-2	56-86	S05	ZENER DIODE 10mA 5V	
D701 D705 D706 D707 D708 D712 D713 D714 D715 D716 D717 D718 D719 D720 D721 D722 D723, D724	57-27	1N2071	DIODE 1A 600V	
D709 D710 D711	57-56	SOM30	DIODE 100A 3000V	
D403, D406, D407, D408, D409, D410, D415, D501 D105-1 D105-2, D106-1 D106-2, D107-1 D107-2 D108-1 D108-2 D109-1 D109-2 D110-1 D110-2 D111 D112	56-56	1N4149	DIODE 10mA 75V	
D411	56-74	MZ836 2	DIODE 100mA 8.2V	
D101-1, D101-2, D102-1, D102-2	417-654	SF800TT	DIODE	C CUT OFF A
ZD401, ZD402, ZD404, ZD405	417-118	2N3393	TRANSISTOR USED AS DIODE	EMITTER COLLECTOR BASE CUT OFF OR CUT OFF

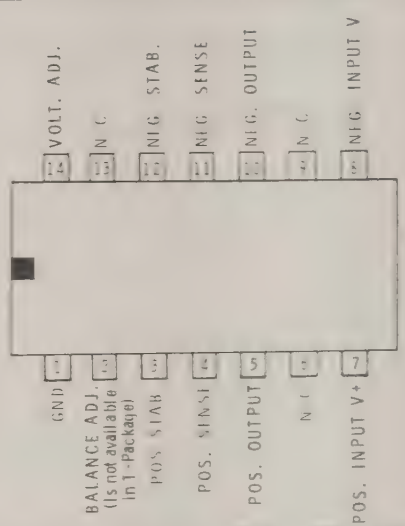
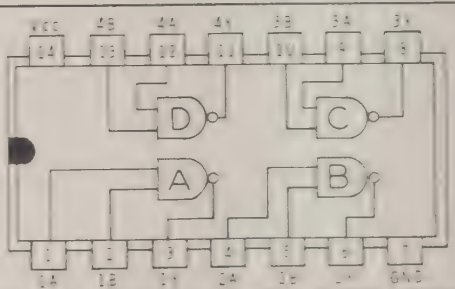
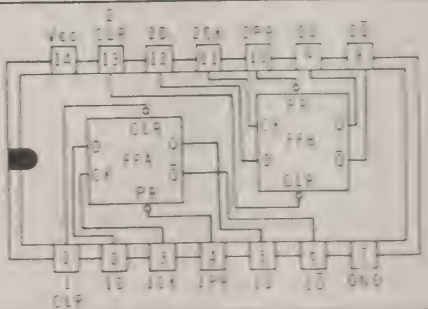
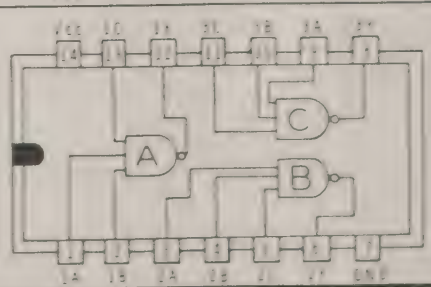
TRANSISTORS

TRANSISTORS	HEATH PART NUMBER	MAY BE REPLACED BY	BASING DIAGRAM
Q402, Q701, Q705 Q115-1, Q115-2	417-118	2N3393	
Q707	417-201	X29A829	
Q708	417-234	2N3638A	
Q401, Q503, Q104-1 Q104-2, Q105-1, Q105-2, Q114-1, Q114-2, Q116-1, Q116-2, Q117-1, Q117-2, Q118-1, Q118-2, Q119-1, Q119-2, Q121, Q122.	417-235	2N4121	
Q506, Q513, Q518	417-237	SE6020	
Q706, Q702	417-224 417-834	MPSU05 MPSU10	
Q703	417-289	2N6109	
Q704	417-296	TA311	
Q504, Q505	417-154	2N2369	
Q102-1, Q102-2, Q103-1, Q103-2, Q110-1, Q110-2, Q111-1, Q111-2, Q403, Q501, Q502, Q514, Q515	417-292	2N5771	
Q106-1, Q106-2, Q107-1, Q107-2, Q112, Q113, Q123, Q511, Q512, Q516, Q517	417-293	2N5770	

Transistors (Cont'd.)

TRANSISTORS	HEATH PART NUMBER	MAY BE REPLACED BY	BASING DIAGRAM
Q507, Q508, Q510, Q519, Q520	417-245	D40N1	
Q509	417-805	2N4889	
Q404	417-806	TIS75	
Q405/Q406	417-814	P401	
Q101A/B-1 Q101A/B-2	417-815	SPA1004	
Q108-1, Q108-2, Q109-1, Q109-2	417-134	MPS6520	
Q120-1, Q120-2,	417-801	MPSA20	

INTEGRATED CIRCUITS

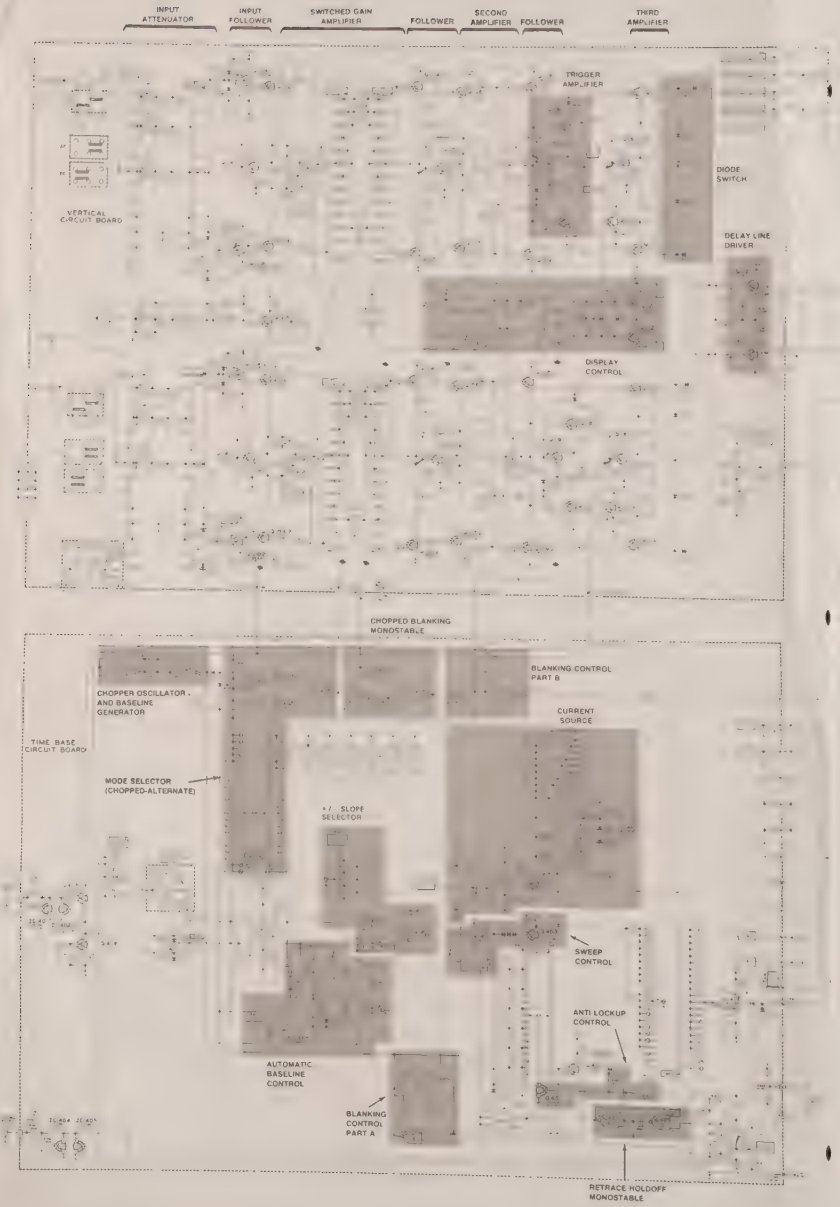
INTEGRATED CIRCUITS	HEATH PART NUMBER	MAY BE REPLACED BY	DESCRIPTION	LEAD CONFIGURATION (TOP VIEW)
IC101	443-85	SG4809N	-15 VOLT REGULATOR	
IC400 IC401 IC402 IC403 IC404 IC405	443-0	SN7400N	QUADRUPLE 2-INPUT POSITIVE-NAND GATES	
IC406	443-6	SN7474N	DUAL D-TYPE POSITIVE EDGE TRIGGERED FLIP-FLOPS WITH PRESET AND CLEAR	
IC407	443-15	SN7410N	TRIPLE 3-INPUT POSITIVE-NAND GATES	

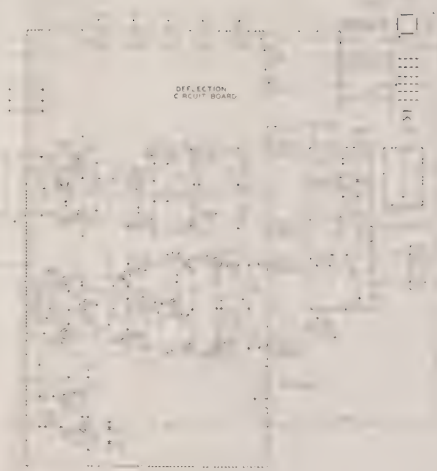
NOTES:

1. REFER TO THE CHASSIS PHOTOGRAPHS AND CIRCUIT BOARD X-RAY VIEWS FOR THE PHYSICAL LOCATION OF PARTS.
2. REFER TO THE COMPONENT IDENTIFICATION SECTION FOR THE TOLERANCE AND WATTAGE OF COMPONENTS SHOWN ON THE SCHEMATIC.
3. ALL CAPACITOR VALUES LARGER THAN 1.0 ARE IN PF UNLESS OTHERWISE SPECIFIED. CAPACITOR VALUES LESS THAN 1.0 ARE IN µF
4. RESISTOR VALUES ARE IN OHMS (K = 1000, M = 1,000,000).
5. □ INDICATES A LETTERED WIRE CONNECTION ON A CIRCUIT BOARD.
6. ⏚ INDICATES CIRCUIT GROUND.
7. ⊖ INDICATES A PART MOUNTED ON THE CHASSIS, ALTHOUGH ITS LOCATION IN THE SCHEMATIC SUGGESTS ANOTHER LOCATION.
8. THIS SYMBOL ⟫⟪ INDICATES A CIRCUIT BOARD-TO-CONNECTOR CONNECTION. THE NUMBER FOLLOWING THE CONNECTOR NUMBER INDICATES THE PARTICULAR PIN NUMBER. FOR EXAMPLE: C4 MEANS, CONNECTOR C, PIN 4.
9. CIRCUIT COMPONENT NUMBERS ARE IN THE FOLLOWING GROUPS:

1 - 99	PARTS ON CHASSIS.
100 - 299	PARTS ON THE VERTICAL CIRCUIT BOARD.
401 - 499	PARTS ON THE TIME BASE CIRCUIT BOARD.
501 - 599	PARTS ON THE DEFLECTION CIRCUIT BOARD.
601 - 699	PARTS ON THE CONTROL CIRCUIT BOARD.
701 - 799	PARTS ON THE POWER SUPPLY CIRCUIT BOARD

10. ⬭ INDICATES A DC VOLTAGE MEASURED FROM THE POINT INDICATED TO GROUND WITH THE VERTICAL AMPLIFIERS BALANCED, THE TIME/CM SWITCH IN THE EXT POSITION, AND THE HORIZONTAL POSITION CONTROL CENTERED.
11. ⬭* INDICATES A DC VOLTAGE THAT VARIES WITH THE SETTING OF THE DC TRIGGER CONTROL R176.
12. ⬭** INDICATES A DC VOLTAGE MEASURED FROM THE POINT INDICATED TO THE CRT CATHODE (PIN 13).
13. TRANSISTOR TRANSISTOR LOGIC (TTL) LEVELS ARE AS FOLLOWS: A LOGIC 0, OR LOW, IS < 0.8 VOLTS. A LOGIC 1, OR HIGH, IS > 2.0 VOLTS BUT < 5.5 VOLTS.





SCHEMATIC OF THE
HEATH
DUAL TRACE OSCILLOSCOPE
MODEL IO-4510/SO-4510

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Part of SPI 169-04

Circuit Board Module Service Policy

Service facilities are available at our factory and at Heathkit Electronic Centers to service the circuit board modules used in the Model IO-4510 Oscilloscope. After you isolate troubles to a particular circuit board, you may return the board for repair under the terms of this policy. This service policy applies to the following circuit board modules:

CIRCUIT BOARD MODULE	SERVICE LABOR FEE*
Vertical	$18.00
Time Base	$12.00
Deflection	$10.00
Power Supply	$7.00
Control	$3.00
Special service fee for all boards at one time	$40.00

*Parts additional after expiration of warranty period.

In Warranty – Within 90 days of purchase when any of the modules listed are returned to any Heath service facility, defective parts will be replaced with no charge for parts and labor. Modules that require service due to causes other than defective parts will be repaired at the fixed charge listed for that module.

Out of Warranty – After your 90-day kit warranty expires, any of the modules listed (when returned to a Heath service facility) will be repaired at the fixed labor charge listed for that module, plus the cost of any replaced parts.

HOW TO RETURN CIRCUIT BOARDS BY MAIL

Save one packing carton in case you ever need to return a circuit board for service. Your kit may contain a special carton for this purpose. It has red rectangles on its sides so it can be easily recognized and receive priority handling. Save both the carton and some loose packing material for future use. Include the following information in the package:

1. A letter describing the symptoms observed in your Oscilloscope.
2. The chassis series number (find this on the blue and white label).
3. Date of purchase and invoice number.
4. Authorization for us to return your repaired circuit board COD for the service, parts, and shipping charges (if applicable).

Ship the carton by insured parcel post to "Heath Company, Benton Harbor, Michigan, 49022."

IMPORTANT – The policy stated above applies only to the circuit boards named. If the problem appears to be elsewhere, check with our Technical Consultant Section at the factory or your nearest Heathkit Electronic Center before returning the kit or any components for service.

FOR PARTS REQUESTS ONLY

- Be sure to follow instructions carefully.
- Use a separate letter for all correspondence.
- Please allow 10 - 14 days for mail delivery time.

DO NOT WRITE IN THIS SPACE

INSTRUCTIONS

- Please print all information requested.
- Be sure you list the correct **HEATH** part number exactly as it appears in the parts list.
- If you wish to prepay your order, mail this card and your payment in an envelope. Be sure to include 10% (25¢ minimum, $3.50 maximum) for insurance, shipping and handling. Michigan residents add 4% tax.

  Total enclosed $_____
- If you prefer COD shipment, check the COD box and mail this form. COD ☐

NAME _____

ADDRESS _____

CITY _____

STATE _____ ZIP _____

The information requested in the next two lines is not required when purchasing nonwarranty replacement parts, but it can help us provide you with better products in the future.

Model # _____ Invoice # _____

Date Purchased _____ Location Purchased _____

LIST **HEATH** PART NUMBER	QTY.	PRICE EACH	TOTAL PRICE
TOTAL FOR PARTS			
HANDLING AND SHIPPING			
MICHIGAN RESIDENTS ADD 4% TAX			
TOTAL AMOUNT OF ORDER			

SEND TO: **HEATH COMPANY**
BENTON HARBOR
MICHIGAN 49022
ATTN: PARTS REPLACEMENT

Phone (Replacement parts only): 616 982-3571

THIS FORM IS FOR U.S. CUSTOMERS ONLY
OVERSEAS CUSTOMERS SEE YOUR DISTRIBUTOR

CUT ALONG DOTTED LINE

FOR PARTS REQUESTS ONLY

- Be sure to follow instructions carefully.
- Use a separate letter for all correspondence.
- Please allow 10 - 14 days for mail delivery time.

DO NOT WRITE IN THIS SPACE

INSTRUCTIONS

- Please print all information requested.
- Be sure you list the correct **HEATH** part number exactly as it appears in the parts list.
- If you wish to prepay your order, mail this card and your payment in an envelope. Be sure to include 10% (25¢ minimum, $3.50 maximum) for insurance, shipping and handling. Michigan residents add 4% tax.

  Total enclosed $_____
- If you prefer COD shipment, check the COD box and mail this form. COD ☐

NAME _____

ADDRESS _____

CITY _____

STATE _____ ZIP _____

The information requested in the next two lines is not required when purchasing nonwarranty replacement parts, but it can help us provide you with better products in the future.

Model # _____ Invoice # _____

Date Purchased _____ Location Purchased _____

LIST **HEATH** PART NUMBER	QTY.	PRICE EACH	TOTAL PRICE
TOTAL FOR PARTS			
HANDLING AND SHIPPING			
MICHIGAN RESIDENTS ADD 4% TAX			
TOTAL AMOUNT OF ORDER			

SEND TO: **HEATH COMPANY**
BENTON HARBOR
MICHIGAN 49022
ATTN: PARTS REPLACEMENT

Phone (Replacement parts only): 616 982-3571

THIS FORM IS FOR U.S. CUSTOMERS ONLY
OVERSEAS CUSTOMERS SEE YOUR DISTRIBUTOR

SERVICE INFORMATION

The following Heath Company services are available if you need them: Replacement Parts, Technical Consultation, and Factory Service. Address all correspondence to:

HEATH COMPANY
Benton Harbor, Michigan 49022

For prompt service, use a separate letter for each department you write to.

Replacement parts and repair service are also available at your nearest Authorized Service Center or Heath Electronic Center. These Centers are listed in your Heath Catalog.

REPLACEMENT PARTS

If a replacement part is needed, please include the following information in your letter:

1. Part number and description.
2. Model Number and Series Number of the equipment.

If your equipment is in the Warranty period, add:

3. Date of purchase.
4. Nature of defect.

Heath Company will fill your order promptly. Please DO NOT RETURN PARTS unless they are requested. Parts that are damaged through carelessness or misuse by the customer will not be replaced without cost.

TECHNICAL CONSULTATION

You can write to our Technical Consultants for help with any Heath equipment, or for answers to any questions about the use of this equipment.

The completeness and accuracy of the advice mailed back to you depends entirely on the information in your letter. Be sure to include:

1. The Model Number and Series Number of the equipment (on blue and white identification label).
2. Date of purchase.
3. An exact description of the difficulty. Include switch positions, connections to other units, operating procedures, voltage reading, and any other information you think might be helpful.
4. List everything you have done in attempting to correct the difficulty.

FACTORY SERVICE

If you do not have qualified repair services at your disposal, you can return your equipment to the Heath Company Service Department to have it repaired for a minimum service fee. (Equipment that has been modified will not be accepted for repair.) Refer to Shipping Instructions for details on how to package and ship the equipment.

To be eligible for replacement parts under the terms of the Warranty, equipment returned for factory service must be accompanied by the invoice or the sales slip, or a copy of either. (If you send the original invoice or sales slip, it will be returned to you.)

SHIPPING INSTRUCTIONS

Check the equipment to see that all parts are in place. Then, wrap the equipment in heavy paper. Place the equipment in a strong carton, and put at least three inches of resilient packing material (shredded paper, excelsior, etc.) on all sides between the equipment and the carton.

Seal the carton with gummed paper tape and tie it with a strong cord. Ship it by prepaid Express or insured Parcel Post to:

HEATH COMPANY
Benton Harbor, Michigan 49022

Attach a letter, containing the following information to the outside of the carton:

1. Your name and return address.
2. Date of purchase.
3. A brief description of the difficulty.
4. Your authorization to ship the repaired unit back to you C.O.D. for the service and shipping charges, plus the cost of parts not covered by the Warranty.

YOUR HEATH FACTORY ASSEMBLED PRODUCT ONE-YEAR LIMITED WARRANTY

If you are not satisfied with our service - warranty or otherwise, or with our products, write directly to our Director of Customer Services, Heath Company, Benton Harbor, Michigan 49022. He will make certain your problems receive immediate, personal attention.

Our attorney insists that we describe our warranty using all the necessary legal phrases in order to comply with the new warranty regulations. Fine. Here they are:

For a period of one year after purchase, Heath Company will replace or repair free of charge any product that is defective either in materials or workmanship. We warrant that during the first full year after purchase, our products, when used in accordance with our printed instructions, will meet published specifications.

If your Heath factory-assembled product malfunctions or fails to operate at any time during the warranty period, through no fault of yours, we will service it free upon proof of purchase and delivery at your expense to the Heath factory, or any Heathkit Electronic Center (units of Schlumberger Products Corporation), or any of our authorized overseas distributors.

You will receive free consultation on any problem you might encounter in the use of your Heath product. Just drop us a line or give us a call. Sorry, we cannot accept collect calls.

Our warranty does not cover and we are not responsible for damage caused by misuse or fire or unauthorized modifications to or uses of our products for purposes other than advertised. Our warranty does not include reimbursement for customer assembly or set-up time.

This warranty covers only Heath factory assembled products and is not extended to allied equipment or components used in conjunction with these products. **We are not responsible for incidental or consequential damages.** Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

HEATH COMPANY
BENTON HARBOR, MI. 49022

The Heath Company reserves the right to discontinue products and to change specifications at any time without incurring any obligation to incorporate new features in products previously sold.

MP MASTER
MA32471